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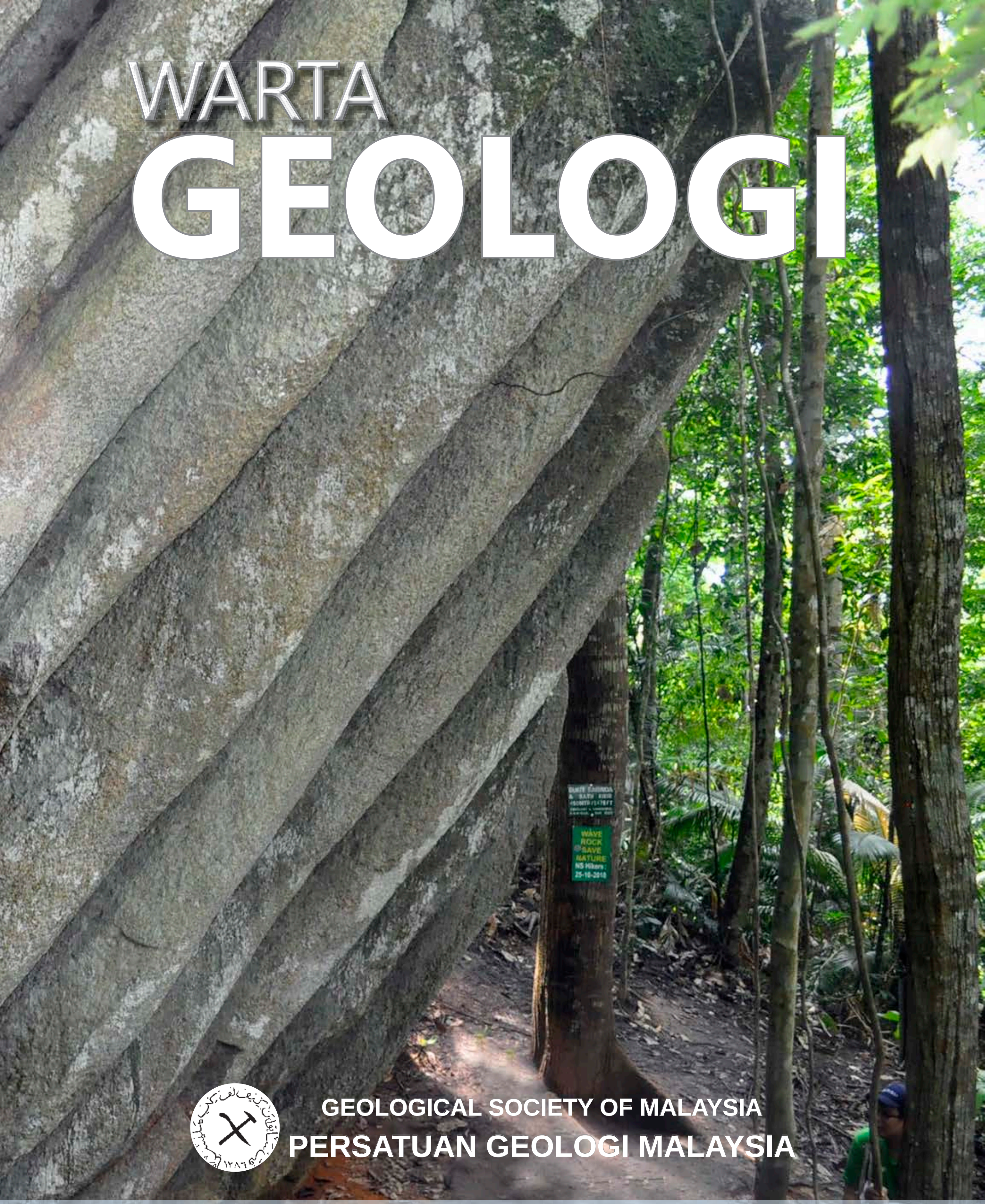

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Residual shear strength of shales from the Gemas Formation based on ring shear tests

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Abstract: Fresh, dark grey to black, shales with minor sandstones of the Triassic Gemas Formation outcrop at the slope cut between Km 81.30 and 81.05 (southbound) of the North-South Expressway near Ayer Hitam in Johore State. The beds strike 165° with eastward dips of 35° to 43° and have thickness of between 0.2 and 1.5 m. Over-lying the fresh bedrock along an irregular boundary is a bleached zone, some 14 to 18 m thick, comprising light grey to white, *in situ* oxidized shales and sandstones. Three samples were collected from a thick shale bed; fresh samples A and B at 18 m and 15 m depth, respectively, and a bleached shale sample C at 11 m depth. All samples were air dried, finely ground, and then passed through a wire mesh sieve with 180 μm aperture sieve. The remoulded samples were tested with the Bromhead ring shear apparatus, employing the pre-shearing test procedure with multi-stage loading. Plots of shear stress versus cumulative horizontal shear displacement under low normal stresses (<150 kPa) yield failure envelopes with residual friction angles of 27.4°, 27.4° and 27.9° for samples A, B, and C, respectively. Under moderate to large normal stresses (150-350 kPa), plots of shear stress versus linear displacement sometimes slope upward due to increased friction as a result of sample extrusion and settlement of the top platen. It is concluded that the pre-shearing test procedure with multi-stage loading is best suited for low to moderate, effective normal stresses (<250 kPa). Based on the test results, the residual friction angle for shales from the Gemas Formation is between 27° and 28°.

Keywords: Gemas Formation, shale, ring shear tests, residual friction angle

INTRODUCTION

In the case of most landslides, the formation of a shear zone or shear surface involves disruption of an existing fabric and its replacement by a fabric dominated by the effects of shear (Bromhead, 1986). This alteration of the fabric results in a decrease in the strength properties of earth materials. The shear strength with the original material fabric is known as the "peak strength", and the strength under large shear deformation is known as the "residual strength" (or also sometimes called the ultimate or large deformation strength) (Bromhead, 1986).

The shear box has been widely used to obtain the peak shear strength parameters of soil and, has in more recent years been modified to determine the residual strength by continual forward and reverse shearing of a sample. The ring shear apparatus developed by Bishop *et al.* (1971) allows a continuous shearing of sample in one direction as does the less sophisticated Bromhead ring shear apparatus which has become more widespread in use for it is relatively easier to operate. Test results obtained using the Bromhead apparatus, however, have been treated with some reservation by practicing engineers on the grounds that the determined residual friction angles are under-estimates of the true values (Hawkins & Privett, 1985). Hawkins & Privett (1985) have shown that for remoulded samples, similar results can be obtained using the Bromhead apparatus as that obtained using the conventional reversal shear box.

The Bromhead ring shear apparatus allows testing of an annular sample, some 5 mm thick with inner and outer diameters of 70 and 100 mm, respectively that is confined radially between concentric rings (Bromhead, 1979). The sample is compressed vertically between porous bronze loading platens by means of a counter balanced 10:1 ratio lever loading system. A rotation is then imparted to the base plate and lower platen by means of a variable speed motor and gearbox driving through a worm drive. This causes the sample to shear close to the upper platen which is artificially roughened to prevent slip at the platen/soil interface (Wykeham Farrance, 1988). Settlement of the upper platen during consolidation or shear can be monitored using dial gauge mounted on top of the load hanger.

In a comprehensive literature review, Rigo *et al.* (2006) noted that the residual strength of transported soils and soils resulting from weathering of sedimentary rocks is extensively described in the geotechnical literature with well-known examples being the over-consolidated clays, clays and clay shales of northern Europe and North

America. Rigo *et al.* (2006) also noted that there is a significant lack of published data on the residual strength of soils in tropical areas.

In Peninsular Malaysia, there is limited published data on the residual shear strength of both fresh and weathered sedimentary and metamorphic rocks. The shear strength of mudstones from the Triassic Semanggol Formation at the Muda Dam in Kedah State was reported to be close to the residual value with a good correlation between field and laboratory determined residual friction angles (φ_r) of 17.5° to 19° (James, 1969). Field and laboratory shear tests on undisturbed and remoulded samples of sheared mudstones from the Muda Dam were also reported to yield a residual friction angle of 18°, whilst peak shear strengths were more variable (Clarke *et al.*, 1970). In Singapore, a basic friction angle (φ_b) of 32° has been determined from portable shear box tests on rough sawn, sandstone blocks from the Triassic Jurong Formation (Pitts, 1988).

Soil shear box tests along a pre-cut surface in weathered graphitic-quartz-mica schist under low normal stresses (<10 kPa) and limited displacements have yielded a residual friction angle of 26.5° (Raj, 1988). Bromhead ring shear tests on the weathered graphitic-quartz-mica schist furthermore, have been shown to be only reliable for low normal stresses (<150 kPa), yielding residual friction angles of 24.7° to 25.8° (Raj, 2019).

In this short note are presented the results of laboratory tests carried out with the Bromhead ring shear apparatus to determine the residual shear strength of fresh and bleached shale exposed at a slope cut close to Air Hitam in Johore state.

METHODOLOGY

Slope cuts for the construction of the North-South Expressway in Peninsular Malaysia have led to several exposures of completely to slightly weathered, and fresh bedrock. One of these cuts is between Yong Peng and Ayer Hitam in Johore State, where fresh (unaltered) and bleached sedimentary strata of the Gemas Formation are exposed (Figure 1). Three samples were collected at different depths along a single thick shale bed at the cut to determine the residual shear strength of fresh and bleached shale. Samples A and B of fresh, dark grey shale were collected at 18 m and 15 m depths, whilst sample C of bleached shale was collected at a depth of 11 m (Plate 1).

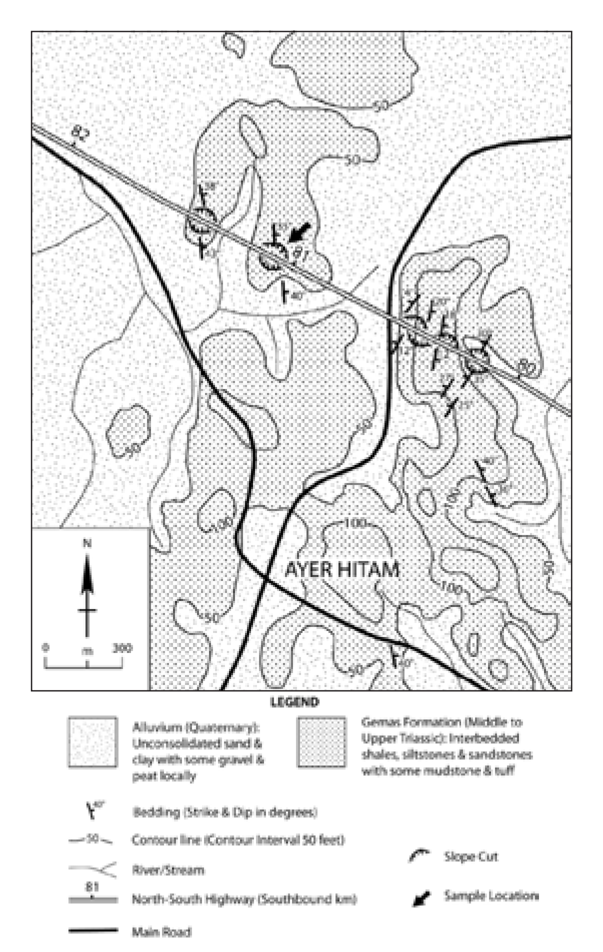

Figure 1: Geology map of the Air Hitam area, Johore. (After Sanisah binti Ahmad, 1992; Wahid Abdul Rahman, 1983)

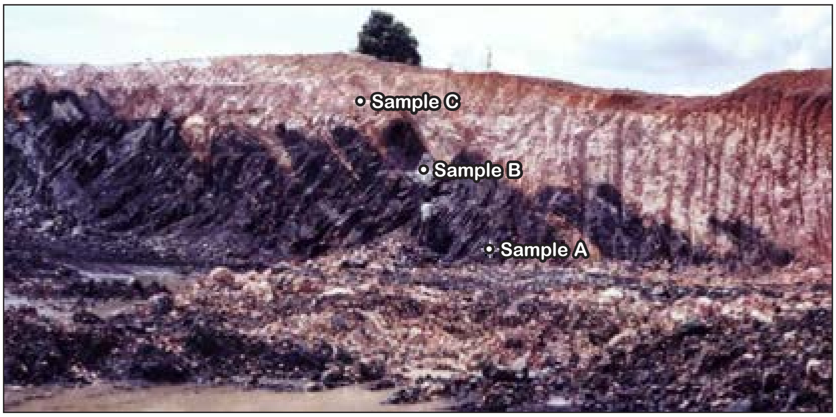

Plate 1: Outcrop showing bleached (pallid) zone over fresh bedrock and location of samples A, B and C.

The samples were first air dried, and then finely ground with a mortar and pestle before being passed through a 180 µm wire mesh sieve. Densities, unit weights and apparent porosities of representative specimens of the three shale samples were also determined employing the saturation and bouyancy technique described in ISRM (2007).

Several test procedures have been proposed for the Bromhead ring shear apparatus; the first being the single stage procedure which provides a good estimate of the residual strength at effective normal stresses below 200 kPa (Stark & Vettel, 1992). The pre-shearing procedure facilitates creation of a shear plane and reduces the length of horizontal displacement needed to reach the residual condition, though there is often extrusion of a substantial amount of soil during the shearing (Wykeham Farrance, 1988; Anayi *et al.*, 1988). In the multi-stage procedure, an additional strength often develops during consolidation and shearing, probably due to wall friction as the top platen settles into the specimen container (Stark & Vettel, 1992). The flush procedure has also been proposed where increasing the thickness of the specimen prior to shear reduces the wall friction and thus gives a more reliable results (Stark & Vettel, 1992).

The pre-shearing test procedure with multi-stage loading was adopted for this study as this is the procedure recommended by the manufacturer of the Bromhead ring shear apparatus (Model WF36859) (Wykeham Farrance, 1988). A displacement rate of 0.048 mm/min was adopted for shearing of the samples. The average effective shear stress acting on the pre-formed slip surface was calculated from the recorded values of two load gauges and this plotted against the corrected average linear displacement calculated from the recorded values of angular displacement. The effective shear stress at maximum corrected linear displacement plotted against the effective normal stress then defined the "complete failure envelope" which actually represents the Mohr-Coulomb failure envelope (Lambe & Whitman, 1973; Hawkins & Privett, 1985).

GEOLOGICAL SETTING OF SAMPLING SITE

The sampling site is located between km 81.30 and 81.05 (southbound) of the North-South Expressway where a slope cut exposes fresh and unaltered, dark grey to black, shales and fine-grained sandstones (Figure 1). The shales are the predominant lithology with individual bed thickness between 0.5 and 1.5 m whilst the sandstone beds are 0.2 to 1.0 m thick. Joints of variable orientations and lengths are present in the beds which strike about 165°, and dip eastwards at 35° to 43°.

In the top three benches of the slope cut, the shales and sandstones are white to light grey in color and form a distinct bleached or pallid zone, some 14 to 18 m thick (Plate 1). The bleached zone overlies the fresh (unaltered) bedrock along an irregular boundary controlled by the overlying topography and inherent bedding (Plate 1). Seepage has been observed and indicates the presence of an unconfined groundwater table located at the bottom of the bleached zone. The bleached zone has thus developed from *in situ* alteration of the strata due to lowering of the groundwater table and aeration of bedrock. Bleaching (i.e. loss of original dark grey to black colors) is thus considered to result from oxidation of organic materials originally present in the bedrock.

Correlation with surrounding areas shows the bedrock to be part of the Gemas Formation which mainly consists of rapidly alternating inter-beds of shale, sandstone, tuff, and tuffaceous sandstone and shale, with minor lenticular bodies of conglomerate and limestone (Wahid Abdul Rahman, 1983). Several fossil locations have been found with faunal assemblages of shell imprints of pelecypods and ammonites yielding a reliable Middle to Upper Triassic age (Lum, 1982).

RESULTS

Physical properties of shale samples

Physical properties of the three shale samples show slight variations with the fresh samples A and B having an almost similar dry density and unit weight of 2,536 and 2,533 kg/m^3, and 24.87 and 24.91 kN/m^3, respectively (Table 1). The bleached shale sample C however, shows dry density of 2,231 kg/m^3 and dry unit weight of 21.88 kN/m^3. Some variations of apparent porosities have been observed, with the fresh shale samples A and B having values of 6.4%, and 7.1%, respectively, while the bleached shale sample C has a porosity of 11.4% (Table 1).

Linear effective shear stress versus corrected linear displacement

Plots of effective shear stress versus cumulative corrected horizontal displacement for low normal stresses (0-150 kPa) for sample A are shown in Figure 2. Plots for low to moderate normal stresses (<250 kPa) of samples B and C are shown in Figures 3 and 4. The plots indicate smooth sliding surfaces with little resistance to displacement due to the parallel alignment of the silt-, and clay-, sized particles during shearing. This feature is similar to that reported by Vaughan (1988) for sedimentary soils, where there is increasing orientation of the low-friction, platy shaped clay particles along slip surfaces with increasing shear displacement.

For moderate normal stresses (150-250 kPa) for sample A (Figure 2), and high normal stresses (250-350 kPa) for samples B and C (Figures 3 and 4) however, the plots appear to slope upward, indicating an increase of resistance with respect to the shear displacement. Observations during testing show that there was extrusion of sample from the sample container during the consolidation and shearing stage under moderate to high normal stresses (>150 kPa). This observation may

Table 1: Physical properties of shale samples from the Gemas Formation.

Sample Number	Lithology (Vertical Depth)	Dry Density (kg/m³)	Saturated Density (kg/m³)	Apparent Porosity (%)	Dry Unit Weight (kN/m³)	Saturated Unit Weight (kN/m³)
A1	Fresh Shale (18 m depth)	2,588	2,649	6.1	25.38	25.98
A2		2,480	2,541	6.2	24.32	24.92
A3		2,547	2,611	6.4	24.98	25.60
A4		2,530	2,599	6.9	24.81	25.49
Average		2,536	2,600	6.4	24.87	25.56
B1	Fresh Shale (15 m depth)	2,581	2,653	7.2	25.31	26.02
B2		2,502	2,577	7.5	24.80	25.44
B3		2,560	2,624	6.4	25.10	25.73
B4		2,490	2,563	7.2	24.42	25.13
Average		2,533	2,604	7.1	24.91	25.58
C1	Bleached Shale (11 m depth)	2,305	2,432	12.7	22.60	23.85
C2		2,157	2,258	10.1	21.15	22.14
Average		2,231	2,345	11.4	21.88	23.00

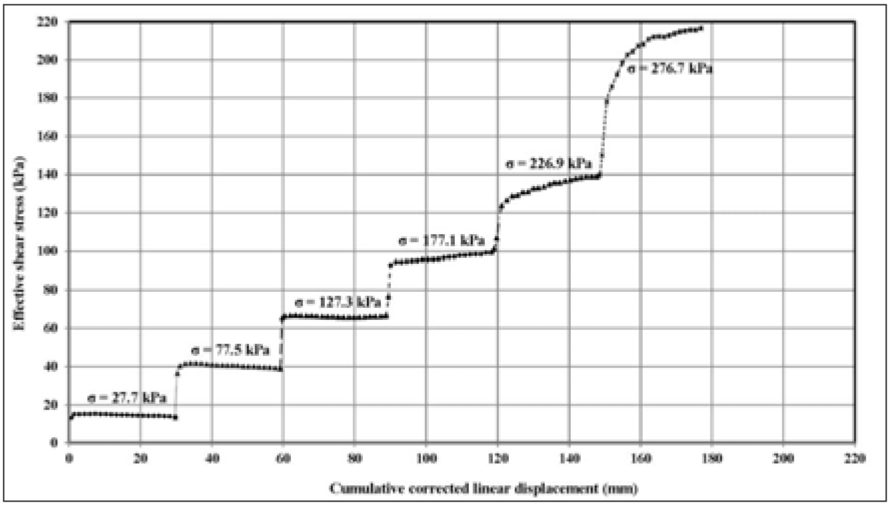

Figure 2: Effective shear stress versus cumulative corrected linear displacement - Shale sample A.

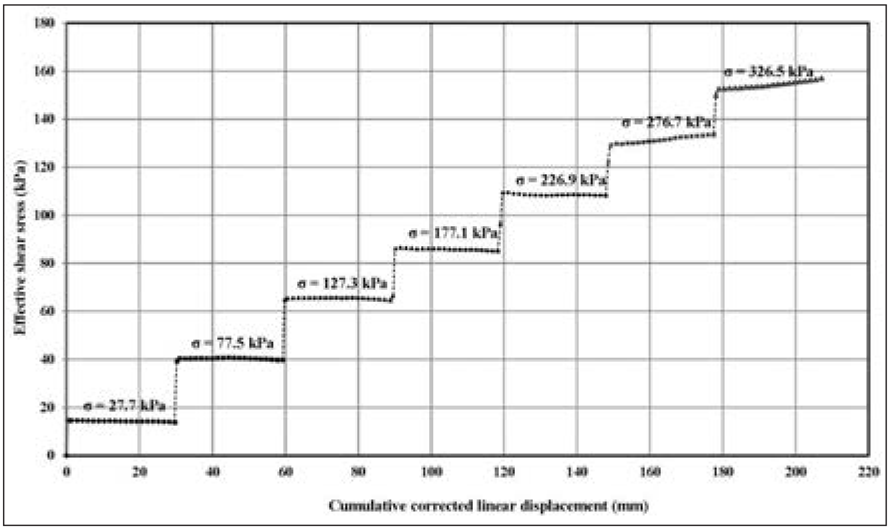

Figure 3: Effective shear stress versus cumulative corrected linear displacement - Shale sample B.

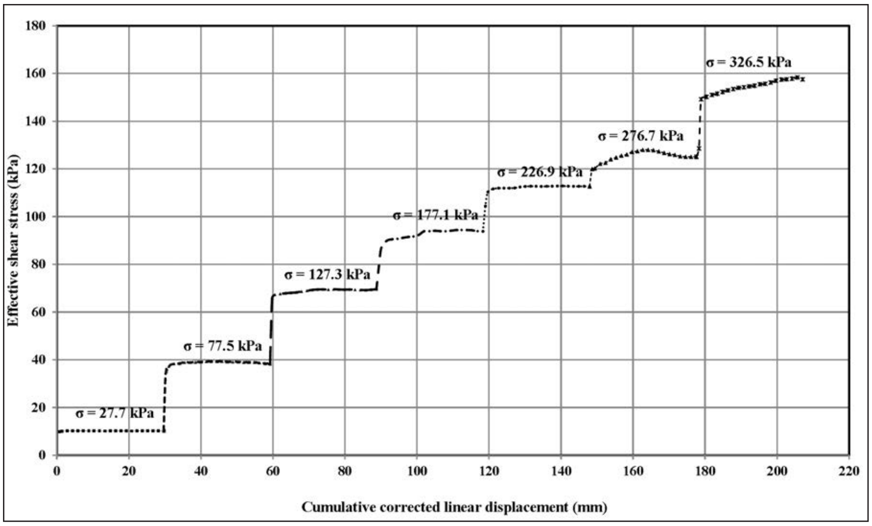

Figure 4: Effective shear stress versus cumulative corrected linear displacement - Shale sample C.

Table 2: Analyses of results of Bromhead ring shear tests in terms of Mohr-Coulomb failure envlope.

Linear Equation	Normal Stress (kPa)	Residual Friction Angle (φ°)	R^2
Sample A: y = 0.5175x kPa	0 - 150	27.4	1.0000
Sample B: y = 0.5192x kPa	0 - 150	27.4	0.9997
Sample C: y = 0.5292x kPa	0 - 150	27.9	0.9840
Sample B: y = 0.4909x kPa	0 - 250	26.1	0.9952
Sample C: y = 0.5147x kPa	0 - 250	27.2	0.9913

Note: R^2 = Correlation coefficient

imply the limitation of the multi-stage loading procedure for there is an increased wall friction due to sample extrusion and settlement of the upper platen into the specimen container during shearing (Stark & Vettel, 1992; Raj, 2019). Extrusion of sample during pre-shearing may also contribute to the increased wall friction (Wykeham Farrance, 1988; Anayi *et al.*, 1988).

Failure envelope

Analysis of Bromhead ring shear tests involves determination of the residual friction angle from the gradient of the linear relationship between the average effective shear stress and effective normal stress, i.e. the plot which defines the "complete failure envelope" (Hawkins & Privett, 1985). This plot represents the Mohr-Coulomb failure envelope which is a line drawn tangent to the Mohr circles plotted to represent the state-of-stress at the peak points of stress-strain curves of soil shear strength tests (Lambe & Whitman, 1973). The "complete failure envelope" has been shown to be a curve in many Bromhead ring shear tests, and it was suggested by Hawkins & Privett (1985) that the residual friction angle is dependent upon the effective normal stresses acting along the sliding plane.

For the tested samples, distinctive linear failure envelopes are obtained for low effective normal stresses (<150 kPa); the gradients yielding residual friction angles of 27.4°, 27.4° and 27.9° with correlation coefficients exceeding 0.98 for samples A, B and C, respectively (Table 2). For samples B, and C furthermore, linear failure envelopes are obtained for low to moderate effective normal stresses (0-250 kPa). The gradients yield residual friction angles of 26.1° and 27.2°, with correlation coefficients exceeding 0.99 (Table 2). A failure envelope for sample A under moderate effective normal stress (150-250 kPa), however, was not considered due to erroneous test results resulting from sample extrusion. Exclusion of test results for samples B and C under large effective normal stress (250-350 kPa) is also due to the same reason.

DISCUSSION

The results clearly show that the pre-shearing test procedure with multi-stage loading is only applicable to determining the residual shear strength of the fresh and bleached shale under low to moderate effective normal stresses (<250 kPa). Tests at greater effective normal stress may lead to extrusion of sample during consolidation and shearing and result in higher friction in the sample.

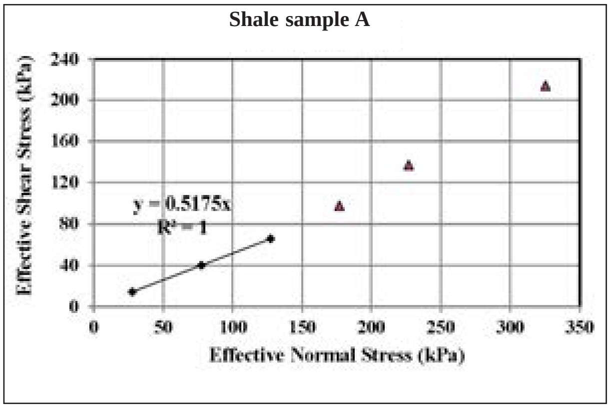

Figure 5: Effective shear stress versus effective normal stress (complete failure envelope) - Shale sample A.

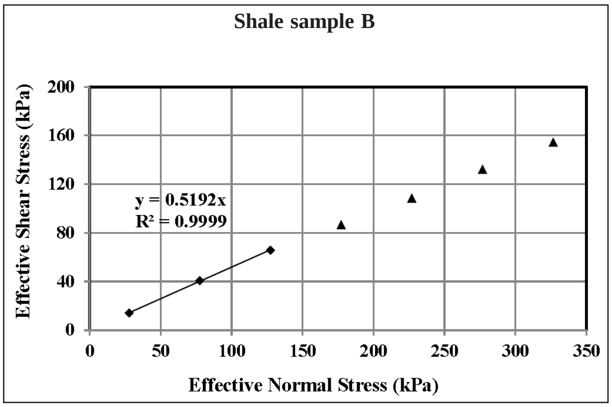

Figure 6: Effective shear stress versus effective normal stress (complete failure envelope) - Shale sample B.

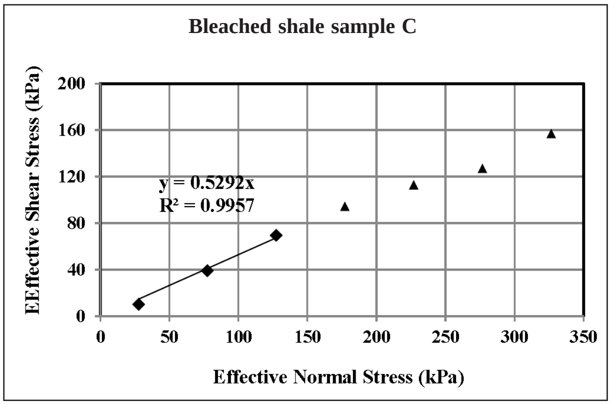

Figure 7: Effective shear stress versus effective normal stress (complete failure envelope) - Shale sample C.

The results also show that under low to moderate, effective normal stresses (<250 kPa), there is very little difference in the value of the residual friction angle (φ_r) for both the fresh (unaltered) and bleached shale samples (Table 2). Bleaching of the shales thus has little effect on its' residual shear strength.

CONCLUSION

It is concluded that bleaching has had little effect on the residual shear strength of shakes from the Gemas Formation; fresh shale having a residual friction angle of 27.4^{o,} and bleached shale, an angle of 27.9^{o}. It is further concluded that the pre-shearing test procedure with multi-stage loading is ideally only applicable to determination of the residual shear strength of the shales under low to moderate, effective normal stresses (<250 kPa).

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Soft soils: A study on their electrical resistivity values and geotechnical properties (porosity, SPT and particle size distribution)

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Abstract: Soft soils pose abundant engineering issues due to its low bearing capacity and shear strength. Comprehensive study on soft soil's physical properties such as shear strength and ability to store water (porosity) could help in devising the optimum ground improvements and foundations techniques. Therefore, physical properties of soft marine clay in Nibong Tebal were thoroughly studied using 2-Dimensional Resistivity Imaging (2-DRI) method in conjunction with porosity measurements, standard penetration test values (SPT-n) and particle size distribution (PSD) analysis. The 2-DRI profile depicts three lithologies, which are unsaturated topsoil, saturated soft clayey soil and saturated sandy soil in the area. The soft soil extends up to 32 m in thickness where it overlies the sandy layer and could be correlated back to lithology profile from borehole record. Additionally, soil samples were collected at three locations along the survey line for porosity measurements via saturation porosimetry method. The samples demonstrate that the clay layer has a very large porosity range and signifies that the soil will compress tremendously under load. On the other hand, SPT-N values of the soft clay is also very low; thus, could be classed as very soft to soft cohesive soil with very low shear strength as compared to a higher range SPT-n values of the sandy layer. The PSD result also compliments the 2-DRI, porosity and SPT results to show distinct differences between topsoil and the soft clay layer in terms of the presence of fine grains. These results further indicate that the thick upper layer is not capable of bearing immense loads such as high-rise infrastructures due to the soil's high porosity and low shear strength. Hence, the area must undergo ground remediations prior to any infrastructure developments on the land.

Keywords: Soft soil, porosity, shear strength, excessive settlement, Nibong Tebal, SPT

INTRODUCTION

Soft soils are soils composed of fine clayey particles in conjunction with high water content in their pores; therefore, contributes to the soils' low shear strength and bearing capacity. In light of the extensive distribution of clay throughout the world, land instabilities are a common event especially in regions with high rainfall as the interaction between clay and water results in the disintegration of the clay (Diaz-Perez *et al.*, 2007; Tan, 2001). Soft soils cause many engineering problems due to excessive settlement of the soil during and after construction phases as soft soils have high compressibility and porosity (Mamat *et al.*, 2019).

For safety measures, porosity and permeability of soils are assessed prior to constructing infrastructures, slope protections, dams and bridges (Lambe & Whitman, 2008). Due to rapid urbanization in Malaysia, developers are beginning to utilise these problematic soft soils. This calls for a thorough understanding of soft soils' characteristics to assist researchers and practitioners in formulating optimum and cost-effective land remediations and foundation techniques prior to any construction process (Mamat *et al.*, 2019).

Therefore, this paper aims to characterize soft soil's physical properties such as electrical resistivity values, soil shear strength and ability to store water (porosity) using geophysical and geotechnical methods by conducting a study at Nibong Tebal.

STUDY AREA AND GEOLOGY

Nibong Tebal, Seberang Perai (Malaysia) is covered with soft marine clay deposits as a result from sea level transgression during Mid-Holocene (Hassan, 1990; Raj, 1992). This simultaneously hinders high rise infrastructure developments in the area.

The area sits on a relatively flat topography with less than 20 m height from sea level in a three-km radius. Submerged during Mid-Holocene high sea levels, the area has since become dry land after the retreat of the shoreline from its maximum inland position. The area is part of Parit Buntar Member (Gula Formation), which consists of soft-marine clay that could reach up to 15 m thickness deposited in marine and/or mangrove environment (Hassan, 1990; Raj, 1992). Figure 1 shows the geology of Nibong Tebal and its surroundings.

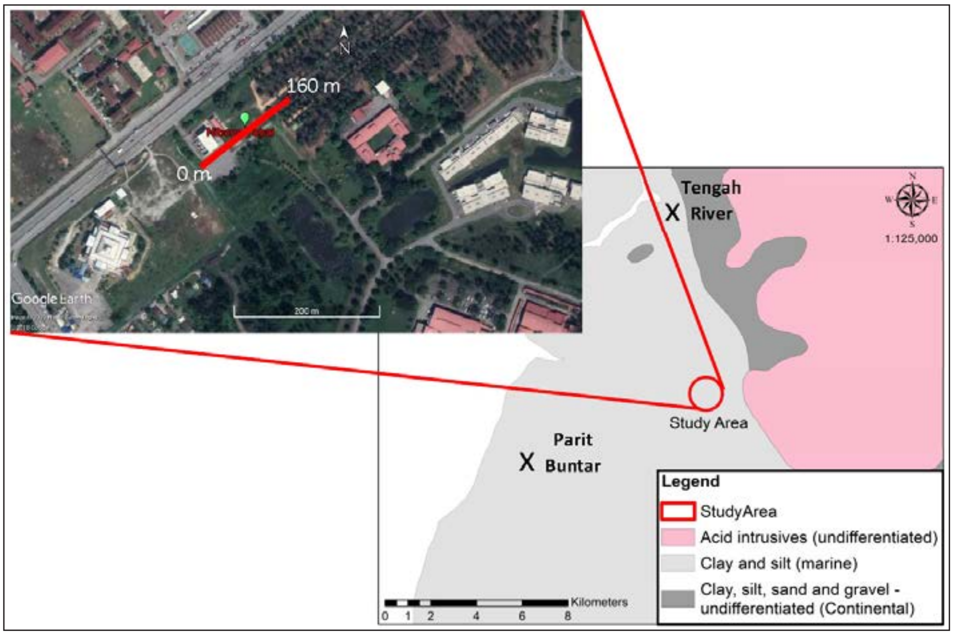

Figure 1: Orientation of resistivity line on site and the geology of its surrounding. (Department of Mineral and Geoscience Malaysia, 1985; Google Earth Pro, 2020).

METHODS AND MATERIALS

The geophysical survey was the primary method for this study where 2-Dimensional Resistivity Imaging (2-DRI) survey was chosen. The acquired 2-DRI data is supported by porosity data from hand auguring on site where porosity saturation technique was applied onto the soil samples. Standard penetrating test values (SPT-n) of the soil were also included.

Geophysical survey

Based on a simple four-electrode configuration, 2-DRI survey employed a multi-electrode resistivity meter system on 41 electrodes to increase the coverage area of the ground and the number of data acquired on site (Loke, 2004) such as illustrated in Figure 2. Using Schlumberger array configuration, a constant electrode spacing of 4 m was chosen to give a 160 m total length of the resistivity (Figure 3) where the line was designed to cut across an existing borehole. The measured 2-DRI data was then subjected to least-squares inversion in conjunction with a smooth constraint to obtain true resistivity values of the ground. From the 2-DRI profile, the extension of soft soil at Nibong Tebal site was distinguished prior to studying its physical characteristics from geotechnical methods.

Geotechnical methods

Geotechnical data executed in this study are porosity and SPT-n obtained from hand auguring and existing borehole record respectively in order to study the physical properties of soft soils. The borehole record was also used to verify the distribution of soft soil obtained from 2-DRI. Stainless Steel Soil Core Sampling Mini Kit, which

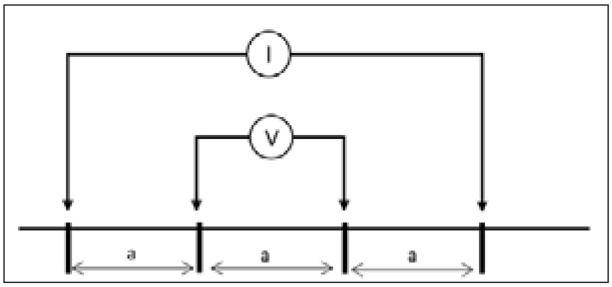

Figure 2: An electrical circuit based on four-electrode configuration used in the survey where *I* represents ammeter, *a* represents electrode spacing and *V* is the voltmeter (Loke, 2004).

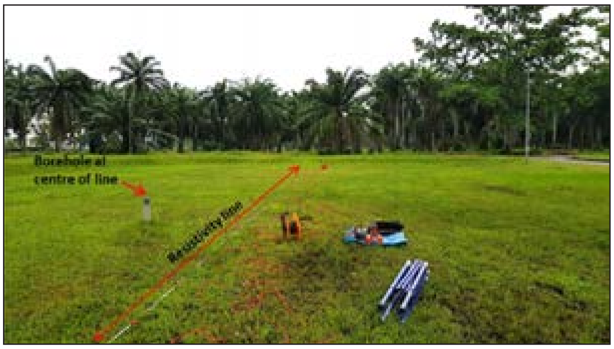

Figure 3: Resistivity survey conducted on site and the location of borehole relative to the line.

consists of auger and soil core sampler, were used to collect undisturbed soil samples for porosity measurements via saturation porosimetry test for measured porosity, $\phi_{measured}$. This test is widely used by researchers including American Society for Testing and Materials (ASTM) Standard

(2015), Kuila (2013) and International Society for Rock Mechanics (2007). As the samples are saturated, soil porosity was obtained based on the association between the saturated pores (void volume) and bulk volume of soil as shown in Eq. (1). By calculating the difference between the fully saturated and dehydrated (oven-dried), $\phi_{measured}$ was easily acquired.

$$\phi_{measured} = (\text{Void volume}(cm^3)) / (\text{Bulk volume}(cm^3)) \quad (1)$$

The samples were also subjected to particle size distribution (PSD) analysis, which consists of mechanical and wet sieving to determine the amount of fine grains in the soft soil. PSD analysis refers to the distribution of dry soil mass over a range of particle sizes based on Stokes' law where the produced PSD curve provides information on the percentage of fine grains (silt and clay) present in bulk of soil based on size classification. The preparation of samples for PSD analysis was conducted according to ASTM 2217 (1998) whereas hydrometer analysis and mechanical sieving follow ASTM D422-63 (2007). The combination of the two analyses produced a PSD curve where the distribution of grain sizes of soils was identified. The analysis was conducted only on samples that represent the saturated soil (depths 1.8 m, 2.8 m, and 3.8 m) to assess the presence of fine-grains in the saturated soil. Lastly, SPT-n of the soil were obtained from an existing borehole record where the bore hole is situated at the centre of the survey line.

RESULTS AND DISCUSSION

With RMS error of 5.7 %, the 2-DRI profile of the ground is considered accurate according to Oualid (2018) and Abdul-Nafiu *et al.* (2013). From the profile (Figure 4), the ground in this survey has low resistivity values ranging from nearly 0 – 1200 Ωm in the covered 32 m depth (Figure 4). The ground can be distinguished into three layers; unsaturated topsoil, saturated soft clayey soil and saturated sandy soil. The saturated soft soil was identified by its low resistivity values of ≤10 Ωm attributed to the high surface conductivity of the soil and its water-loving properties; therefore, causing the soil to be able to hold large amount of water in its pores.

The soft soil is situated beyond depths of 0.9 – 1.6 m from the ground surface with a thickness that reaches up to 32 m, varying along the survey line with unsaturated layer overlying this layer. Considering its thickness, the soft soil has high potential in causing engineering problems.

Three holes were augured along the 2-DRI survey line as illustrated in Figure 4. Undisturbed soil samples were first collected at 0.8 m depth while the subsequent sample collections were conducted at depth intervals of 1 m. The water table was at 1.15 m depth, which implies that all soft soil samples were in naturally saturated condition except for the soil samples at 0.8 m depth. The soil porosity, $\phi_{measured}$, results at Nibong Tebal were tabulated in Table 1. The results show that all soil samples at 0.8 m depth have distinctly different range of $\phi_{measured}$ values

Table 1: Porosity results depicting two soil types along the 3.8 m depth.

Distance of augured hole on line (m)	Depth of soil sample (m)	Porosity (%)	Average porosity of area (%)
61	0.8	40.3	38.0 (top soil) 66.9 (soft soil)
	1.8	58.4	
	2.8	70.1	
	3.8	69.6	
80	0.8	39.5	
	1.8	64.9	
	2.8	67.9	
	3.8	70.4	
89	0.8	34.1	
	1.8	55.4	
	2.8	73.3	
	3.8	71.9	

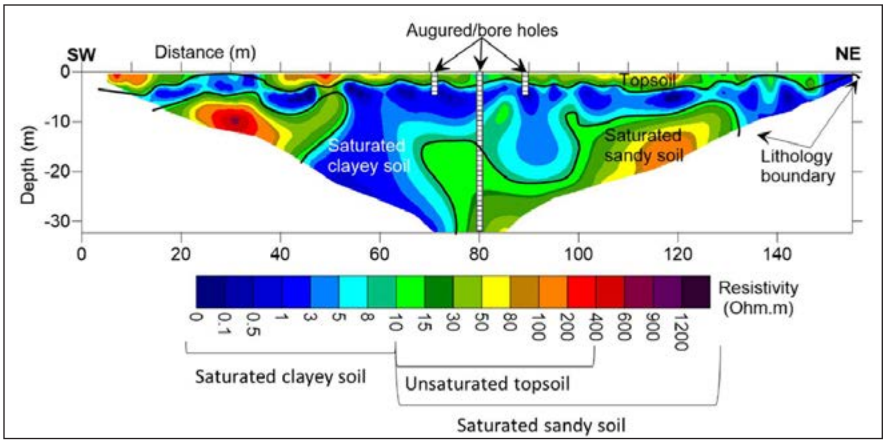

Figure 4: Identified soft soil distribution from 2-DRI result and the locations of augured and bore holes.

(34.05 – 40.29 %) as compared to those at deeper depths (55.4 – 73.3 %). Nearly twice larger in $\phi_{measured}$ values, this signifies that they are of different soil types, where the 0.8 m soil samples are the topsoil while the high porosity soil samples are the targeted soft clayey soil. This results strongly correlate with 2-DRI results in terms of soil profiling. Considering the immense porosity of the soft soil, this explains its low electrical resistivity property, which enables the soil to store immense pore water volume in its pores where the pore water occupies up to of the soft soil. The high conductivity of the pore water dramatically reduces the soft soil's resistivity readings.

Appearance-wise, the soft soil was easily differentiated from the topsoil in terms of colour and texture. Nibong Tebal's fine-textured soft soil is contributed by the high percentage of silt and clay. Its light grey colour with swampy smell also strongly suggests marine origin (Figure 5a). In contrast, the top soil is coarse-textured with reddish-brown colouring (Figure 5b). In addition, the whitish coloured particles in the topsoil sample are polystyrene; therefore, a proof of man-made soil for land stabilisation of the soft soil underneath.

The SPT-n result of the ground obtained from the borehole (Table 2) also agrees with 2-DRI and porosity results as three distinct soil layers having different soil stiffness could be identified; hence, validates each other.

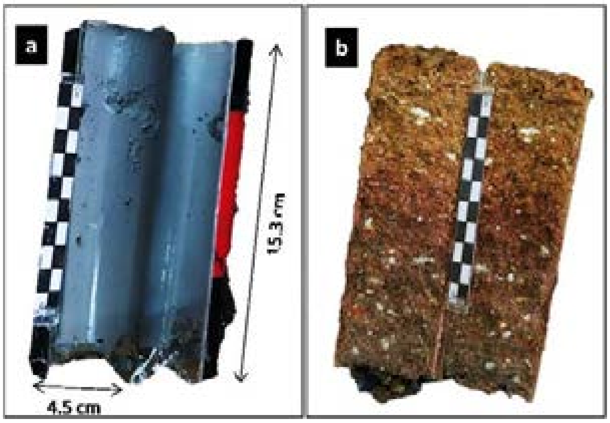

Figure 5: Undisturbed soil samples where a) shows smooth textured soft soil while b) have coarse-textured top soil layer with reddish-brown colouring.

With zero SPT-n value of the soft soil, this depicts its low bearing capacity to support immense load for building structures. Its inability to support buildings proves that optimum ground remediations and foundations are keys in development on soft soil lands.

Meanwhile, results on PSD analysis on the soil samples (Table 3) also supports the classification of the ground. Only the top most soil sample has fine grains of 42.3 % while deeper soil samples have significantly greater amount; 60.8 – 95.8 %. Making up almost the entire bulk of soil, the substantial amount of fine grains explains the high porosity values of the soft soil and the low SPT-n values.

Thick spatial distribution, high porosity and low bearing capacity of the soft soil are ingredients for soil failure. In its natural state, the soil holds a large amount of pore water in its pores. Stress introduced by load induces soil compression via soil rearrangement with pore water as a lubricant in this mechanism (Song *et al.*, 2017). The pore water is also simultaneously being expulsed out of the soil as porosity is reduced as illustrated in Figure 6. This results in land subsidence before finally causing building failure.

Table 2: SPT-n values of the subsurface showing soil strengths while verifying 2-DRI result of three-layer soils in Nibong Tebal.

Depth (m)	Type of soil	SPT-n
0 – 3	Medium stiff clay	6
3 – 15	Very soft clay	0
15 – 30	Medium dense sand	10 – 16

Table 3: PSD analysis results that shows distinct difference between top soil and soft soil in the terms of fine grains presence.

Depth (m)	Presence of particle size (%)	
	<75 µm (silt and clay)	≥75 µm (sand)
0.8	42.3	57.7
1.8	60.8	39.2
2.8	95.8	4.2
3.8	74.0	26.0

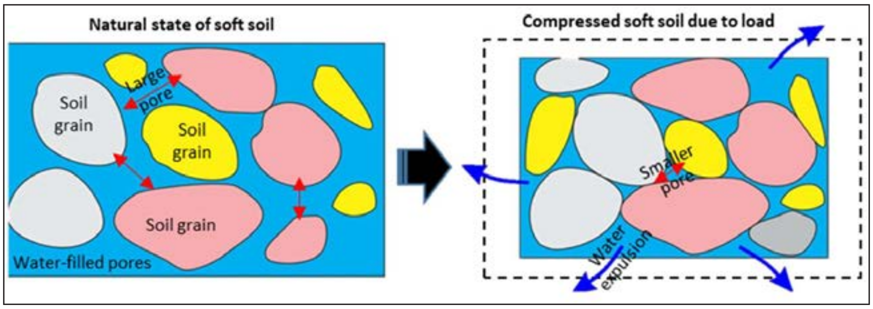

Figure 6: Effect of compression on soft soil where loss of soil volume occurs due to reduction of porosity and pore water.

CONCLUSION

At Nibong Tebal site, the saturated soft soil has very low electrical resistivity values (≤10 Ωm) as a result of large amount of pore water combined with its substantial amount of fine grains lowers the soil's resistivity values. The high porosity of the soil (55.4 – 73.3 %) provide space for pore water to occupy and lubricate soil rearrangement via compression when load is placed on top of the soil. This depicts that porosity plays a pivotal role on a material's bearing capacity.

Furthermore, zero SPT-n value and a thickness of up to 32 m, the soil's low bearing capacity cannot maintain its integrity after the structures are erected, especially high-rise buildings. This is attributed to the compaction of soils as they settle when immense load is introduced; therefore, inducing structural failures.

It is obvious that the area is covered with thick soft soil with high probability for excessive compression. Current soil remediations include soil chemical stabilizers or physically modify the soil via soft soil replacement, expedite pore water dissipation, insertions of prefabricated vertical drains and installation of stone column. However, better ground remediation techniques and foundation designs that are cost-efficient and reliable are still imperative in tackling soft soils. With these physical behaviours of soft soils, they could serve as a guide for researchers to formulate superior designs for soft soil developments to avoid structural damage and loss of lives.

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Discovery of agate geode and nodules at Mount Conner, Semporna, Sabah

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Abstract: An exposure of agate geode and nodules in Mount Conner, Sabah, provides an essential aspect to the geological formation in Semporna. This paper briefly report results from petrography analyses on the agate geode and nodules and its significance to the volcanic rocks and sedimentary rocks formation in Mount Conner. The geode and nodules can be divided into agate, and nodules and most of them are sub-rounded. Nodules are usually small in size and display brownish colour. It commonly occurs in volcanic rocks (dacite and rhyolite) and contained amygdale filled by secondary mineral such as microcrystalline and macrocystalline quartz. In contrast, sedimentary rocks in Mount Conner contain both nodules and geodes, which nodules shows similar characteristic with nodules in volcanic rocks and geodes contained empty vesicles or spaces surrounded by colourless to milky white quartz crystals. Both geode and nodules exhibit conchoidal fracture, while geode shows vesicle features and nodules in volcanic rocks show amygdale texture. The formation of geodes and nodules in Mount Conner might as result of precipitation under low temperature from hydrothermal solution.

Keywords: Geode, Mount Conner, nodule, Semporna

Abstrak: Penemuan geod akik dan nodul di Gunung Conner, Sabah, telah memberikan aspek yang penting kepada formasi geologi di Semporna. Kertas ini secara ringkasnya melaporkan hasil analisis petrografi terhadap geod akik dan nodul, dan kepentingannya terhadap formasi batuan volkanik dan batuan sedimen di Gunung Conner. Geod akik dan nodul boleh dibahagikn kepada akik, kalsedoni dan nodul, serta bersifat separa bulat. Ciri-ciri yang terdapat pada nodul yang tersingkap pada batuan volkanik (dasit dan riolit) ialah ia bersifat padat dengan tiada ruang diantara nodul, berwarna kecoklatan dan mempunyai saiz-saiz yang kecil. Manakala, batuan sedimen di Gunung Conner pula mengandungi kedua-dua jenis seperti nodul dan geod. Nodul mempunyai ciri-ciri seperti yang tersingkap pada batuan volkanik dan geod pula mempunyai vesikel didalamnya yang turut mengandungi kristal kuarza yang tidak berwarna dan berwarna putih susu. Kedua-dua geod dan nodul mempunyai retakan konkoidal dan tekstur amigdal. Pembentukan geod dan nodul di Gunung Conner mungkin disebabkan oleh mendakan dibawah suhu yang rendah daripada larutan hidrotermal.

Kata kunci: Geod, Gunung Conner, nodul, Semporna

INTRODUCTION

The occurrences of geodes and nodules can be found all over the world, and it is mostly associated mostly with volcanic rocks and sedimentary rocks. Geode and nodules tend to have rough, and dull-looking spherical objects which resemble mud balls, however, inside geode have a cavity that contains various types of silica crystals (Makhlouf *et al.*, 2015). Those silica crystals generally show varieties of colour due to elements impurities. Colourless quartz crystals are the most dominant in Mount Conner, Semporna, accompanied by minor milky white quartz. Some quartz rarely shows other colour such as pink, purple, yellow and smoky grey. Geodes are usually filled by quartz crystal however other types of minerals such as calcite, barite, selenite, marcasite, sphalerite, and pyrite might be present (Makhlouf *et al.*, 2015).

The natural geological formation of agate geode and nodules are developed when the gas bubbles remain trapped in the magma, then the silicon deposits itself into a space full of the bubble while forming layers of walls before start solidifying itself. The difference between geode and nodules is geode contains empty spaces and hollow inside while the nodule is compacted totally without spaces. A discovery of agate geode and nodules exposed at the outcrops of dacite and rhyolite and sedimentary rock in Mount Conner, Sabah. The sedimentary rocks consist of sandstone and mudstone. With this background understanding of agate geode, this paper will discuss the various characteristics of the geode and nodules in the chosen study area.

GEOLOGICAL SETTING

The Semporna Peninsula is characterized by Miocene volcanic rock (Kirk, 1968; Hutchison, 1989; Bergman *et al.*, 2000), which shows subduction and OIB-like signatures (James *et al.*, 2019). In Semporna and Dent peninsulas of south Sabah, evidence of Sulu arc discovered on land (Chiang, 2002; Hall, 2012). Semporna is unique in terms of geological setting because most of the land rocks show volcanic arc-subduction setting (James *et al.*, 2019) (Figure 1). The recent tectonic movement had also uplifted the Quaternary coral limestone and formed a group of islands. Part of the Semporna town itself is built on the limestone formation (Morris, 1973) which is surrounded by volcanic rocks. Radiocarbon dating on coral limestone shows age ranges between 18,900 and 36,000 B.P (Taira & Wataru, 1971).

Mount Conner area is mainly covered by dacite and rhyolite lavas. At the south of Mouth Conner, there is an exposure of sedimentary rock outcrop which is underlain by volcanic rocks. The Quaternary deposit in the Mount Conner area formed as part of the extensive marine sediments of the Semporna area. The source of the sediments are from the Upper Tertiary and Quaternary volcanic rock in the surrounding area, which continuously deposited since Early Quaternary to Recent (Kirk, 1962; Lee, 1988). Sediments that are associated with the Quaternary are divided into 2 groups namely Older Quaternary and Younger Quaternary sediment (Kirk, 1962). The Older Quaternary consists of volcanic pebble beds, tuffaceous sandstone, clay, and sandy clay overlain the volcanic rock. This sediment forms the area between volcanic hills at Mount Conner and the Mound Bod Gaya area.

Younger Quaternary sediment or recent alluvium occurs in coastal flats and lower river valleys. Raised coral limestone of younger sediment overlies older Quaternary sediment and volcanic rocks. Raised coral limestone consists of coral and shell debris. The large deposit of raised coral limestone occurs at the Semporna Town area and Bum Bum Island (Kirk, 1962). Observation in the outcrop of volcanic rocks in Mount Conner indicates that nodules unearthed within the dacite and rhyolite lavas but very limited.

CHARACTERISTICS AND PETROGRAPHY

From the hand specimen, nodules in dacite and rhyolite nodules are dark brown and sub-rounded. Whereas for the sedimentary rock, agate geode and nodules can be found in abundance in the layer of shales, but absent of any geode or nodule. McBride *et al*. (1999) explained that in mudstones, only small and volumetrically restricted cavities are presumed to be as nodules, geodes, and vugs. Those geodes and nodules mostly weathered on the surface, and some detached from their host rocks. In this study, the characteristic of the agate geode and nodules are based on types, roundness, colour, diameter, and crystal (Table 1). All the geode and nodules have

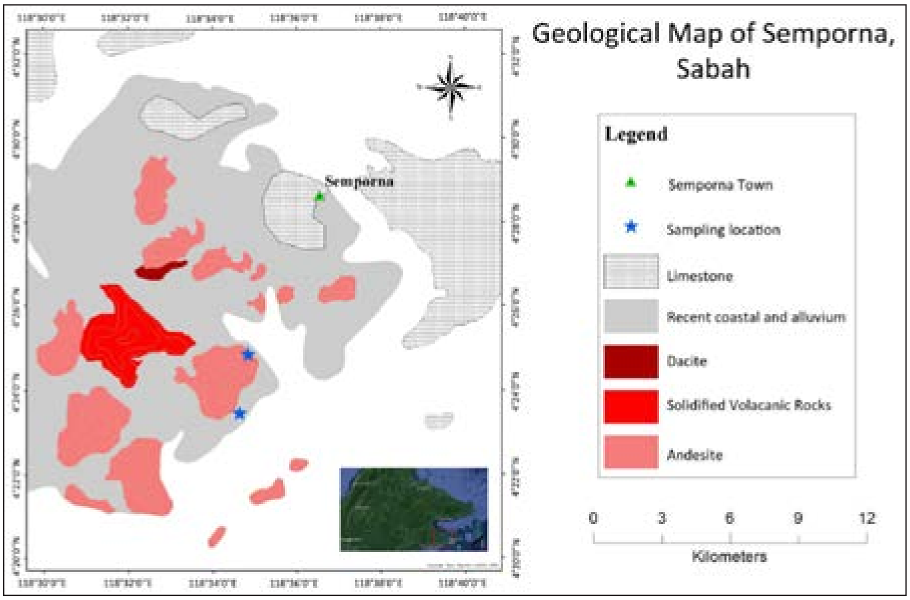

Figure 1: Geological map of Semporna, Sabah.

Table 1: Characteristics of agate geodes and nodules.

	Type	Roundness	Colour	Diameter (cm)	Crystals
Geodes	Agate	Subrounded	Colourless, Clear greyish, Milky white	4 – 12	Quartz (colourless)
Flint nodules	Chalcedony	Subrounded	Milky white, Brownish	7	-
Volcanic rocks nodules	Nodules	Subrounded	Brownish	5	-

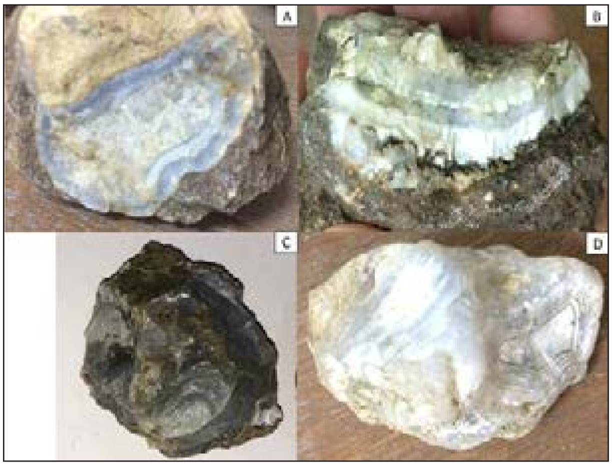

Figure 2: A – B) Agate geode (sedimentary rocks) from Mount Conner, Semporna, Sabah. C – D) The nodules from Mount Conner, Semporna, Sabah.

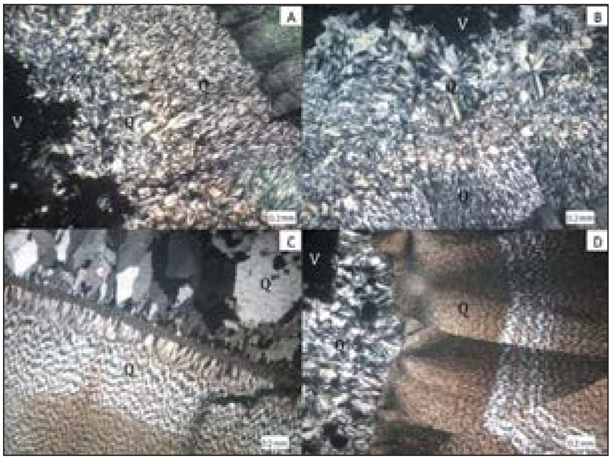

Figure 3: A - B) Geode from sedimentary rocks shows radial or mosaic structure, while the extinction is mostly parallel. C - D) The geode (sedimentary rocks) exhibit periodic extinction bankds along with the fiber direction. Q = quartz, V = vesicle.

similar roundness which is sub-rounded, which indicate gas bubbles do trap in quick flowing magma. The sizes are various and range from 4 to 12 cm in diameter, and some are wider in geodes compared to nodules. Variety of sizes and shapes in geodes might indicate the original cavity as an indication of the precursor for organism or mineral as the dissolved material based on their following formation (Makhlouf *et al*., 2015). Agate geode contains a variety of colours such as colourless, clear greyish, and milky white. The quartz crystals are colourless and milky white, and showing euhedral shape for the inward-projecting crystals. Bands of white and colourless observed in geodes and nodules. The occurrences of coloured banding within geodes might indicate uneven or interrupted growth patterns (McBride *et al.*, 1999). Nodules (chalcedony) have an external layer of agate, and in the middle is mostly milky white, light brown, or brownish of quartz minerals (Figure 2).

Petrography analyses show that agate and nodules are composed of a composition of quartz or chalcedony, and both exhibit conchoidal fracture. The grain size is very fine and shows an aphanitic texture. The conchoidal fracture is similar to geode and nodules from sedimentary rock. The regrowth of silica in geode continues to form from margin and later toward the center (Figure 3a – 3b). Macrocrystalline quartz appears to be slightly more significant in the center compared to the surrounding in a geode (Figure 3a, 3b, 4c and 4d). Rhyolite contains more cavities that filled with a secondary mineral such as

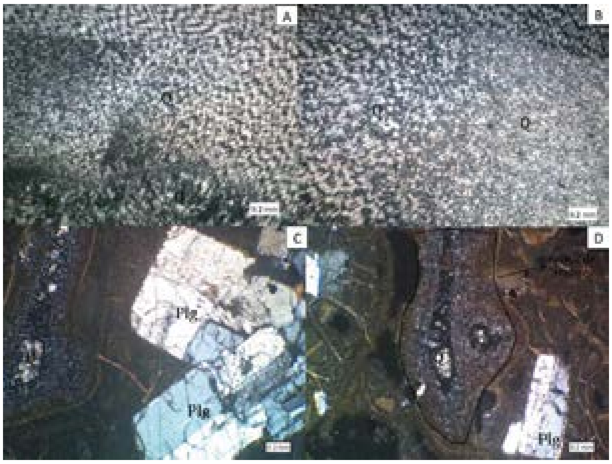

Figure 4: A - B) Flint nodules from sedimentary rocks shows the twisted fibers that exhibit only certain sections of the fibers to be extinct at one time. C – D) The volcanic rocks nodules contain cavities filled with secondary mineral, chalcedony. The amygdale texture is observed in volcanic rocks nodules. Q = quartz, V = vesicle, Plg = plagioclase.

chalcedony (0.2 mm-2.0 mm) compared to dacite lavas. The amygdale texture can be observed that filled with quartz (Figure 4c and 4d) as a results of bubble transport and extraction (Gilg *et al*., 2003). Microcrystalline quartz makes up the almost the entire of geodes and nodules (Figure 3 and Figure 4). Macrocrystalline quartz may form from a silica solution while chalcedony forms from a gel (Moxon, 2014). Moxon (2014) further explained that the microcrystalline quartz and chalcedony might have formed in different silica saturation environment form in different silica environments.

DISCUSSION

The formation of agates connects the volcanic and hypogenic solutions from sources of various ions and organic matter (Lucyna *et al*., 2016). The geode crystallizes in vesicles of former gas, or fluid bubbles may have formed by crystallization from the same silica source from the process of participation of hydrothermal fluids resulting in formation of chalcedony layers and macrocrystalline quartz crystals (Gotze *et al*., 2009). Hydrothermal fluids also participated during the formation of agates in sedimentary host rocks (Gotze *et al*., 2009). It is ubiquitous to find geode and nodules in volcanic rock because gas bubbles are trapped in the magma and created them. The formation of geode and nodules in sedimentary rock is formed slowly from an accumulation of debris, mud, and other sediments. Landmesser (1988) suggested that agate geode formed at low temperatures related to sedimentogenetic and diagenetic conditions.

Taijin & Sunagawa (1994) further suggest that precipitation of geode in low temperature from the hydrothermal solution which invaded into geode opening showing embryonic polymerised particles achieving nanometer size. Furthermore, continuous supply from the aqueous silica at constant low temperature may result in the silica crystallization (Commin-Fischer *et al*., 2010). Nodules in Mount Conner show no sign of a cavity or completely no vesicle. This suggests that the precipitation of silica had filled it up entirely by leaving no space or vesicles in the nodules (Makhlouf *et al*., 2015).

CONCLUSION

Conclusively we found out the following: (1) geodes, and nodules size at mount Conner Semporna is relatively small compared to average geodes and nodules elsewhere; (2) the lack of cavity in the nodule found in mount Conner Semporna is also an indication of silica saturated saturation or alternatively continuos supply of silica from aqueous solution, it could also mean the continuous supply of silica from aqueous. There are various other possibilities with the formation of geode and nodule found at the mount Conner Semporna, one of the many possibilities include the geode formed as a result of precipitation under low temperature from a hydrothermal solution that invaded into the opening of the geode consequent to its embryonic polymerised particle at nanometer; the occurrences of geodes and nodules can be found in Mount Conner, Semporna. Specifically, nodules are abundant in volcanic rocks outcrops as the volcanic rocks is a host rocks since the quartz-chalcedony is not a primary mineral, while sedimentary rocks act as host rocks for geodes and nodules. The types of geode and nodule divided into agate, chalcedony, and nodule. Colourless and milky white quartz crystals are more developed in geodes. Nodules appeared to be fully compacted or fully filled by secondary minerals with no space inside it. In mount Conner Semporna given the samples analyzed both in the field and in the laboratory, we believe that agate and chalcedony from sedimentary rocks and nodules from volcanic rocks were found in mount Conner Semporna. Therefore, it is quite clear that the presence of geode in mount Conner in Semporna shows the massive volcanic activities that would have taken place before their emplacement. That may also have affected the sedimentary rocks that host these geodes and nodules.

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First discovery of *Stegodon* (Proboscidea) in Malaysia

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Abstract: A cheek tooth of *Stegodon*, an extinct genus of Proboscidea, had been discovered in a cave in Gopeng, Perak. The discovery represents the first fossil of *Stegodon* ever found in Malaysia. Embedded in lithified cave infillings are the associated dental remains from at least three or four other different taxa of fossil mammals commonly found among Southeast Asian Pleistocene-Holocene faunas. The finding provides a unique chance for investigations into the evolution dynamics of *Stegodon* in this part of Southeast Asia and the species diversity of Proboscidea in prehistoric Peninsular Malaysia. Fossil mammal assemblages from different phases of Pleistocene-Holocene period collected from karstic caves in Peninsular Malaysia, when considered with similar assemblages from other parts of Southeast Asia, have the potential to contribute to our understanding of prehistoric faunal migrations and species compositional changes among the biogeographic (sub)divisions in Southeast Asia. This may ultimately lead to a better knowledge of the possible paleoenvironmental and paleoclimatic fluctuations that influenced patterns of migration and adaptive responses of mammalian faunas in Quaternary Southeast Asia.

Keywords: *Stegodon*, cave paleontology, Quaternary mammals, Southeast Asia, prehistoric migrations

INTRODUCTION

There has been a wide gap in Quaternary vertebrate paleontological studies since the first major publication in the 1960s (Hooijer, 1962). As a consequent of which, Malaysia is lagging far behind in this important aspect of Quaternary science investigation among the Southeast Asian countries. However, this knowledge gap had been partially filled relatively recent with the report of the first discovery of orangutan (*Pongo* sp.) fossils in Peninsular Malaysia (Yasamin *et al*., 2013), an overview on the elephant fossils and distribution (Lim, 2013) in prehistoric Peninsular Malaysia and a number of new geographic records of prehistoric rat (murinae) species by Sahak *et al*. in 2019 and Sahak (2020) from sites dating back from 500-33 Ky (thousand years). Caves with exceptionally high potential had also been reported from Merapoh (Pahang) which represented the first *Pongo* fossil site in central Peninsular Malaysia (Muhammad *et al*., 2019). Associated fauna includes fossils of the regionally extinct Asian Black Bear (*Ursus thibetanus*) (Muhammad *et al*., 2019) and possibly other higher primates.

To date, about 1000 isolated teeth remains had been collected from several fossil-bearing caves, with globally and regionally extinct taxa: *Pongo*, *Ursus thibetanus*, Hog Badger (*Arctonyx*), Javan Rhinoceros (*Rhinoceros sondaicus*), Sumatran Rhinoceros (*Dicerorhinus sumatrensis*), Lesser Giant Rat (*Leopoldamys minutus*). The rest consists of diversified faunas of Porcupines

(Hystricids), Bamboo Rats (*Rhizomys* spp.), Malayan Sun Bear (*Helarctos malayanus*), Clouded Leopard (*Neofelis nebulosa*), Tiger/Leopard (*Panthera* spp.), Dog/Dhole (Canids), Asian Elephant (*Elephas maximus*), Wild Boar (*Sus* spp.), Sambar Deer (*Cervus unicolor*), medium-sized deer (Cervids), Mousedeer (*Tragulus* spp.), Southern Serow (*Capricornis sumatraensis*), large-sized wild cattle (Bovids), monkeys (Cercopithecines), various murine species and possibly other higher primates.

A routine exploration of caves in Gopeng by a group of cave enthusiasts from the Kinta Valley Watch group on July 26, 2020 had uncovered a peculiar object. Upon initial observation of photos and the actual object in situ within its encasing sediments in the field and consultation with various experts, it had been identified as a cheek tooth of *Stegodon*, a globally extinct genus of Proboscidea. Fossils of *Stegodon* or related forms had been recorded from central and east Africa in Chad, Democratic Republic of Congo, Uganda, Ethiopia, Kenya and Tanzania. Within Asia, species of the genus had been reported from China (both mainland and Taiwan), Japan, India, Pakistan, Nepal, Myanmar, Thailand, Laos, Vietnam, Indonesia (Java, Sulawesi, Sangihe, Sumba, Flores and Timor) and the Philippines (Luzon and Mindanao) but not from Malaysia.

THE CAVE/LOCATION OF THE FOSSIL SITE

The specific location of the discovery site is kept embargoed until the necessary procedures are taken for protection and preservation. An updated publication with complete information of the location and more data after various analyses will be published. The cave is located in a relatively small karst hill (unmarked in any regional topographical maps consulted) with a small stream flowing along the periphery of its cliff. Multi-level notches can be seen along a wall, with some parts forming shelter caves. The height of the notches is at about 2 m high, and extend into the cave. The cave forms two distinct layers that trend towards the southwest and cut through the hill. The upper passage is elevated about 6 m above the ground and forms a narrow cave trending towards the southwest. Fossil-bearing remnants of 0.8 m-thick lithified cave infillings are cemented on both sides of the passage walls. The clastic cave sediment consists of mostly fine sands with some muds, and intercalation of streaky crystalline carbonate, with some subangular rock pebbles. The tooth of the *Stegodon* was embedded approximately in the middle of the passage, about 70 cm from the cave floor. Dental remains of mammals were also found in the soft sediments in the lower passage.

THE FIELDWORK, EXTRACTION AND ONGOING WORK

Metrical data of the exposed section of the tooth were collected as accurately as field conditions allowed using a hand-held vernier caliper. Results from visual observation of the external morphological characters were documented. To ensure the morphological details of the exposed surface of the *Stegodon* fossil can be accurately captured and recorded prior to extraction, dentists used special dental materials to prepare the tooth impression and cast of the fossil. This procedure is essential as any mishandling during extraction might damage the fossil. Before applying to the *Stegodon* tooth, the moulding process had been experimented and improved upon using similar fossil-bearing matrix (collected from other cave sites) in the lab and on an exposed bovid tooth fossil (while still embedded in its encasing matrix) in the field. Extraction had been carried out after the moulding process by using battery-powered drills, hammers and chisels. Extraction was targeted at both the tooth and the encasing matrix immediately surrounding and protecting the fossil tooth. The whole process of moulding and extraction was video and pictorially recorded.

The complete cave passages were mapped for geomorphology and taphonomy description, with information on other features such as the streams and other karst hills in the surrounding gathered. The data give us clues on the depositional environment of the cave infilling and probably can be used for age estimation of the cave. Carbonate grains in the encasing sediment were separated and handpicked for U series age determination

Figure 1: A cheek tooth of *Stegodon* found embedded in lithified cave sediment in Gopeng, Perak.

Figure 2: Morphological details of the exposed surface of the *Stegodon* is captured by moulding prior to extraction.

Figure 3: Extracted tooth in encasing matrix.

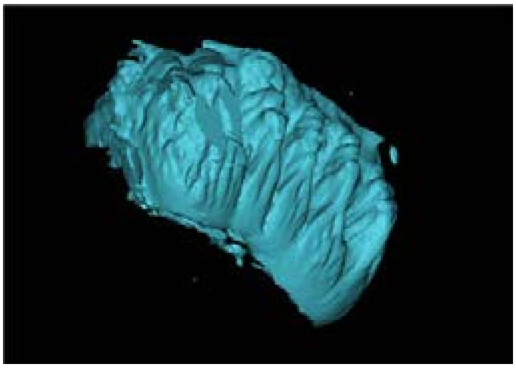

Figure 4: 3D reconstruction image of *Stegodon* tooth fossil using a high precision cone beam computed tomography (CBCT).

and are being tested in National Taiwan University. This initial analysis will be followed by other techniques to be decided in the future.

Detailed morphological studies on the fossil and high-precision imaging using micro-computed tomography (MicroCT) and cone beam computed tomography (CBCT) are being conducted and will be followed by comparison with museum collections to determine the serial position of the tooth and possible species.

ASSOCIATED FAUNA

Associated fauna had been observed and to date, *Pongo*, *Sus* spp., modern elephant (*Elephas* or related form) and a large-sized bovid were found in both of the passages in the potentially rich sediments. Early field observation indicates the lower passage may be of younger age compared to the upper passage. Both passages are likely to give a long record of various taxa that may span tens of thousands of years during the Late Pleistocene or earlier.

CONCLUSIONS

Caves in Peninsular Malaysia have proved to be sites for scientifically important Quaternary fossil materials. These fossil and geological findings can provide answers to some pertinent research questions, such as the evolution and migrations of mammals and their adaptations to habitat changes in this part of Southeast Asia during the Quaternary. Peninsular Malaysia, with its strategic location between continental and island Southeast Asia, very likely acted as one of the key corridors for prehistoric migrations of land mammals and humans. This study is the first step towards developing a niche area for natural history and heritage studies with region-wide implications.

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Identification of unconfined aquifer using 3D resistivity analysis at Simpang 5 area, Semarang, Central Java, Indonesia

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Abstract: Water is a unique property of the Earth and very important to every living organism. The existence of groundwater is only 0.61% of the total water on earth (oceans, rivers, lakes, polar ice, rain). The purpose of this research is to determine the location and depth of the aquifer by using 2D and 3D modeling. The method of research is resistivity method using Schlumberger configuration, where data is collected according to the survey design with coordinate ranging from X:436100, Y:9226880 to X:436680, Y:9227640, and covered by 7 lines. The modeling results indicate that the present groundwater aquifer potential has low resistivity distribution in this area. The spreading of unconfined aquifer is estimated on the north side to the east of Simpang 5 area. This can be seen from syncing the data of line one to six. But the data on line seven is of different patterns with other lines. The existence of groundwater basin is not easily identified on this line. This may be due to the location of Line Seven being located in the area of Ciputra Mall, Horison Hotel and Tlogorejo Hospital with higher consumption of water, thus the decrease in groundwater condition. This may cause conditions such as land subsidence. The results of interpretation based on the modeling show the possibility of an unconfined aquifer with groundwater level at 10-15 m depth with varied end of border groundwater depth.

Keywords: Alluvium, geoelectric, groundwater, unconfined aquifer, Simpang 5, Semarang

INTRODUCTION

Water is a limited natural resource according to time and place. Processing and preservation is absolutely necessary. Utilization of water for various purposes should be done wisely by taking into account the interests of present and future generations. Water has become a primary need for every living being on earth (Nazaruddin, *et al.*, 2017). Increasing population of living creatures has decreases the water supply. Most human generally need about 300 liters of clean water for everyday purposes (Lateef, 2016). Water is found in many parts of the world including oceans, rivers, lakes, polar ice, rain, and ground water. In addition to oceans and polar ice, ground water is another most important source (Ofterdinger *et al.*, 2020). Sub-surface information is one of the most important components of earth-related activities. This information includes the geological structure, type, and physical properties of rocks, array of rocks below the surface, depths, thickness, and distribution, including the condition of aquifers containing ground water.

The city of Semarang as the capital of Central Java province has various geographical characteristics. Semarang City which continues to experience growth both in the field of industry and property makes Simpang 5 area became the center of growth and development in the city. This is because the location of Simpang 5 Semarang is at a very strategic area, easily accessible from all over the city. It also makes the growth of economic, trade and tourism activities very rapid in the region. Rapid growth in the Simpang 5 area requires the availability of clean water sources to support all these activities that are taking place in the region. Water users in Simpang 5 area are increasing with the presence of several hotels, such as Horison Hotel, Citra Land, Graha Santika, Holiday Inn, Luis Kiene, and several malls in the area.

The condition of groundwater extraction in Semarang City, especially Simpang 5 area can be said to have reached a condition that exceeds the balance between ground water supply and the number of taking. It can be seen from the groundwater infiltration data which states that the amount of absorption lost in Semarang City is 5,281,564 m^3 (Shen *et al.*, 2020). The amount indicates a large volume, where if the situation continues, will cause negative impacts on groundwater conditions such as the decrease of groundwater level, quantity, and quality. Taking into account the condition of Simpang 5 area, it is necessary to know the potential of groundwater well in the area so that groundwater management can be carried out in an integrated and sustainable condition. The geophysical method is an appropriate tool for characterizing the geology and sub-surface hydrology (Ibuot *et al.*, 2013). In this research, systematic planning and management to predict the groundwater potential using modern techniques is applied for proper use, protection and management of vital resources (Sultan *et al.*, 2017). The role of geophysical methods in groundwater survey is to understand the adequately and accurately hidden hydrogeological conditions. The basis of any geophysical method is to measure the contrast between the target physical and environmental properties (Saad *et al.*, 2012). A good appreciation of geology is essential in groundwater development programs because geology determines where, how, and how much groundwater quantity and quality are available (Ewusi *et al.*, 2009).

The geophysical method uses an approach based on the contrast of conductivity or resistivity to determine the conductivity distribution or resistivity of the subsurface Earth material, so this method is particularly suitable for identifying lithology units and variations of lithologic units as well as for the study of groundwater and aquifers (Redhaounia *et al.*, 2016; Shen *et al.*, 2020). In addition, this geophysical method is also a popular method because of its low operation cost, simple process, and efficiency in areas with low contrast resistivity (Muchingami *et al.*, 2012). There are several kinds of geoelectric methods, one of which is the resistivity method. It follows the basic principle that each of the rock layers has different resistivity values. The resistance values of each type of rock is determined by their constituent material types, water content, chemical properties of water, and rock porosity (Nakashima & Kawabata, 2020). So by knowing the resistance value of the type of rock layers, we can study the types of rock material, subsurface, and distribution of groundwater in the area. Geoelectric surveys of mapping and sound resistivity methods resulted in information of variations in resistivity rates both laterally and vertically (Luo *et al.*, 2019). At the present time, the resistivity method has become an important and useful tool in hydrogeological studies, mining and mineral mining (Aizebeokhai, 2010).

MATERIAL AND METHOD

Geophysical methods provide an efficient tool for characterizing subsurface geology and hydrology (Ibuot *et al.*, 2013). Geological and geophysical surveys were conducted in the research area to identify potential groundwater in the area. The geological survey aims to identify and map geomorphological and geological features, especially the unit of land and lithologic units exposed in the study area. For geophysical investigations, resistivity survey is an effective method for groundwater investigation.

Resistivity method is a geophysical approach based on the conductivity or contrast resistivity used to determine the conductivity distribution or resistivity of the Earth's substances below the surface, so this method is particularly suitable for identifying lithology units and variations in lithology units as well as for groundwater and aquifer studies (Redhaounia *et al.*, 2016). Moreover it is one geophysical method that is low in cost, simple operation, and is efficient in areas with low contrast resistivity (Muchingami, 2012).

The principle of the resistivity method is to inject an electric current to the earth through the current electrode (a pair of electrodes) and the response received in the form of a potential difference is measured through two potential electorodes. Each measurement uses four electrodes, following Ohm's Law, interrogating the effective point beneath the surface (Cardenas & Markowski, 2010). From the measurement of the differential current and electric potentials, we can obtain variations of electrical resistance in the layer below the measurement point (Supriyadi *et al.*, 2017; Suski *et al.*, 2010). Multi-electrode resistivity survey was conducted using S-Field resistivity resistance. The system is connected to 16 stainless steel electrodes, which are placed in a straight line with a constant distance through a multi-core cable. The Schlumberger configuration is used in this study (Figure 1). The resistivity survey was conducted with a 10 m electrode spacing that provided a spreading length of about 150 m with the deepest penetration of approximately 50 m. The location of the study is shown in Figure 2.

Based on the measured physical quantities, the Schlumberger electrode arrangement aims to measure the electrical potential gradient. The geometric factor for this Schlumberger electrode arrangement corresponds to Equation 1, while the magnitude of the Geometry Factor (K) for the Schlumberger configuration is shown in Equation 2.

$$K = 2\pi/((1/r_1 - 1/r_2) - (1/r_3 - 1/r_4) \quad (1)$$

$$K=\pi\ (b^2/a - a/4) \quad (2)$$

The research steps include the measurement of path, determining the width between electrodes (a), installing electrodes based on the electrode arrangement used in the Schlumberger configuration, and activating the resitivity meter device which will inject the electrical current into the ground through the geoelectric cables.

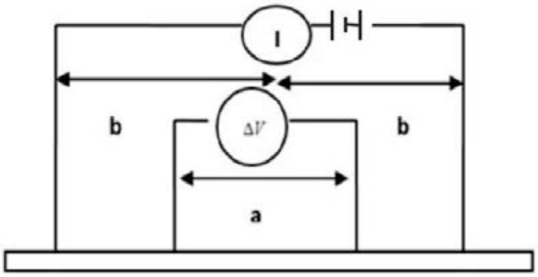

Figure 1: Schlumberger electrode configuration (modified after Hermawan, 2016).

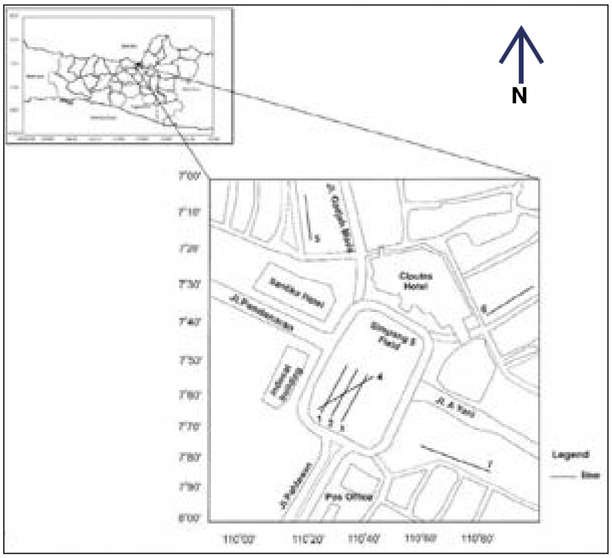

Figure 2: Survey design at the research location Simpang 5, Semarang.

Data was obtained in the form of primary data of the measured results using Ms.Excel. The measured parameters are voltage (V) and current strength (I). The magnitude of the voltage value (V) and the current strength (I) is used to determine the apparent resistivity value, as shown in Equation 3.

$$\rho_a = k \, \Delta V / I \qquad (3)$$

where ρ_a is apparent resistivity, k is geometry factor, ΔV is different of potential (V_{MN}), and I is Current Flow (I_{AB}). ΔV and I are based on Figure 1.

RESULTS AND DISCUSSION

The 3D resistivity modeling was processed using Rockwork software. The distribution of resistivity values obtained from the inversion of Res2Dinv software processing is used as the beginning of 3D cross-section processing using Rockwork Software. From the range of resistivity values, the existence of groundwater at the research location can be determined. Figure 3 shows the distribution of control points modeled from the data obtained at the time of measurement.

The 3D modeling used only 4 trajectories which are scattered in the Simpang 5 field, that is the first, second, fourth and third track as cross sections based on 2-D and 3-D electrical imaging surveys tutorial (Loke, 2004). The next three trajectories are not included in the 3D modeling as they are only used as a comparability path for the accuracy of data. The distance of Simpang 5 Field with the track that is on the fifth, sixth, and seventh tracks is considered less accurate for modeling because it will cause considerable interpolation.

The 3D cross-section is modeled in a block shape, so that it can be observed more clearly from all sides. The coordinates of this box are at the maximum position of X

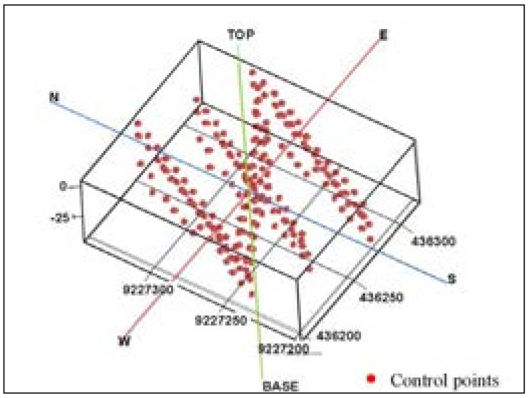

Figure 3: Control points distribution using Rockwork software.

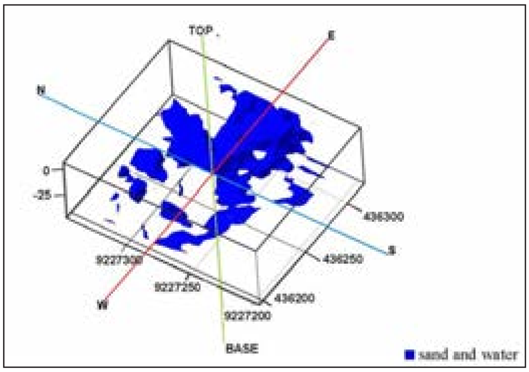

Figure 4: 3D imaging of the anomaly results in 0.25-1 Ωm resistivity range.

436320 and Y 9227345, as well as the minimum positions X 436195 and Y 9227195. The elevation modeled on the 3D cross section is from 6 m to -50 m from the ground. The distribution of resistivity values according to rock type is shown in Table 1.

The study area generally consists of several layers with different resistivity values. The results of 3D processing using Rockwork software on the restriction value of 0.25-1 Ωm which predicted ground water obtained results are shown in Figure 4. Restriction of resistivity value is done in order to get the distribution of groundwater basin in the location clearly.

The distribution of a larger number of resistivity is shown in the northeast of the Simpang 5 field. This is reinforced by the sixth track located in the East Pekunden Road area. The sixth track shows that at its southern side, there is more groundwater distribution, and this position is close to the northeastern part of Simpang 5 Square.

The first trajectory precisely in the western part of Simpang 5 Square showed less groundwater distribution than the other paths. From another study, a decrease between 0.2-0.4 m/year in groundwater level that occurred at Graha Santika Hotel located at Simpang 5 was reported (Chen *et al.*, 2010). The decrease in the groundwater level indicates the reduced distribution of groundwater.

Tabel 1: The values of resistivity (Telford *et al.*, 1990).

Materials	Resistivity (Ωm)
Air	0
Sea Water	0,21
Ground Water	0.25-200
Clay	1-100
Sand	1-1000
Copper	1-1,7
Magnesium	4,2
Iron	0,1-25
Alluvium	10-800
Mangan	44-160
Gravel	100-600
Sandstone	200-8000
Limestone	$50\text{-}1\text{x}10^{7}$
Carbon	3000
Saltstone	$30\text{-}1\text{x}10^{13}$
Quartz	$4\text{x}10^{10}\text{–}2\text{x}10^{14}$
Andesite	$17\text{x}10^{1}\text{–}45\text{x}10^{3}$

However, the range of decline is still categorized as low-grade (Zhou *et al.*, 2020).

Simpang 5 area consists of 3 main land layers, namely the first layer of top soil (0 to 10 m) composed of soil. The second layer with a depth of between 10 and 45 m is in the form of sand layer, which indicated the location of aquifer (surface water source). The third layer is a clay layer at a depth of 45 to 80 m. The results of modeling using Rockwork software shows the presence of groundwater distribution at a depth of 15 m below the surface. This layer is identified as a sand layer which is thought to be the site of an aquifer. Furthermore, this layer where the range of resistivity values tend to be small i.e. 0.25-1 Ωm is included in the conductive zone as it is a layer that is easy to conduct electrical current. Based on the resistivity value of the aquiver being less than 1 Ωm, this indicates that it is salty water, caused by intrusion. Therefore, this aquiver is not suitable for consumption such as for drinking or cooking. The location of the groundwater depth in the study area is shown in Figure 5. 3D modeling results using 0.25-1 Ωm resistivity range indicates a volume of ± 55950 m^3, the figure represents only 20 % of all volume modeled using Rockwork software.

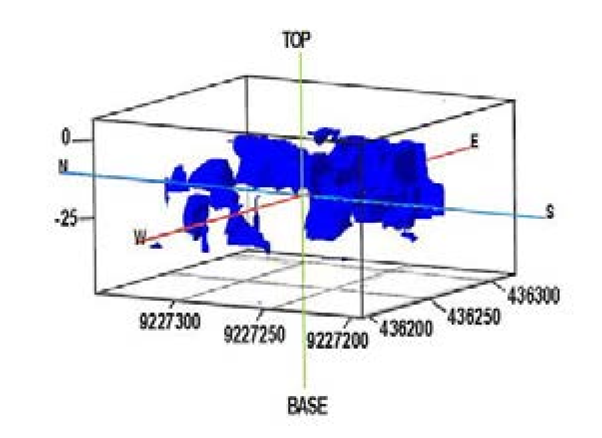

Figure 5: 3D imaging showing the depth of the free aquifer basin in the 0.25-1 Ωm resistivity range, as seen from the southwest.

CONCLUSION

The 3D modeling results indicate the presence of groundwater potential in the study site. In this model, the groundwater resistivity range is between 0.25-0.940 Ωm and indicated an unconfined aquifer because the very salty water may be caused by sea water intrusion. The measured volume is ± 55950 m^3, representing only 20% of all volume modeled using the Rockwork software.

The results of data processing of each measurement path indicate the presence of groundwater layer at Simpang 5 Field, and the potential of ground water tends to be in the north. The seventh location in the Sejora Selatan area has different conditions from other trajectories, presumably this location is experiencing a decrease in groundwater level, caused by the loading of hotels located in the region such as Horison Hotel, Ciputra Mall, and Hotel Santika.

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X-ray diffraction (XRD), X-ray fluorescence (XRF) and Scanning Electron Microscopy (SEM) analysis of potsherds, Sungai Batu Complex, Bujang Valley, Kedah

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Abstract: Archaeological excavations at the Sungai Batu Archeological Complex have unearthed potsherds with monument structures. The discovery of the potsherds enables scientific studies of X-ray diffraction (XRD), X-ray fluorescence (XRF) and Scanning Electron Microscopy (SEM) analysis to be conducted and resolve related issues such as where the raw materials were obtained by the manufacturers. To solve the issue, potsherds were taken from around the ancient river, and scientific analyses was conducted for comparison purposes. Before the clay sample was subjected to the scientific analyses, the samples were cleaned and measured (for weight, thickness and width). Color sampling was also performed. Based on results of the analyses, it clearly shows that the potsherds was produced using raw materials from the ancient river in the Sungai Batu Complex itself and baked at a temperature between 550°C and 650°C.

Keywords: Potsherds, scientific analysis, raw material

INTRODUCTION

The archaeological research at the Sungai Batu Complex reveals evidence of the oldest structure and smelting sites in Southeast Asia. The dating was determined using the optical stimulate luminansen *(OSL)* and radiocarbon techniques. The results clearly show that the structure was built since 582 BCE (Figure 1 and Table 1) and the iron industry started to grown since 535 BC (Figure 2).

The structure here has been classified as river jetty, administrative and ritual sites (Naizatul, 2012; Iklil Izzati, 2014; Mohd Hasfarisham, 2014; Shamsul Anuar, 2015; Nurashiken, 2016; Suhana, 2016). Previous excavations at all monument sites in Sungai Batu have found potsherds that suggested pottery was part of the daily use in this area. This interpretation has similarities with Chia (1997, 2003a, 2003b) and Suresh (2011) who also proposed potsherds was used for cooking, storage and trading as well as in religious ceremonies.

According to Peacock (1959), Solheim (1990), Mohd Kamaruzzaman *et al.* (1991), Chia (1995, 1997, 2003a, 2003b) and Gani *et al.* (2015), a scientific study on pottery should be carried out to determine the raw material used in the process of producing the artifacts. In addition, by conducting a scientific analysis, the information on combustion technologies can also be known and classified. To obtain such information, quantitative and scientific analysis of XRD, XRF and SEM were applied to 15 potsherds and 17 soil samples from Sungai Batu Archaeological Complex. The scientific analysis carried out only involved potsherds fragments found at the river jetty

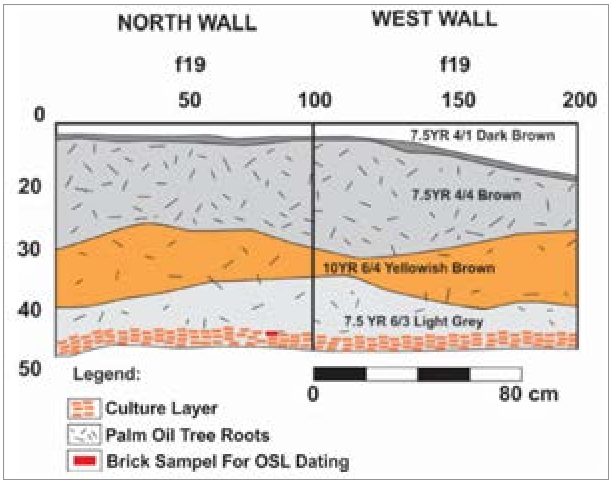

Figure 1: A stratigraphic layer showing the location of in-situ brick sample and revealing the date 582 BCE.

Table 1: Result of OSL Dating from f19 trench.

Site	Trench	Spit	Sample Classification	OSL Dating	BCE: Before Century
SB2D	F19	5 (40-50 CM)	Floor	-	582 BCE

and administrative sites to determine whether local raw materials were used in the process of potsherds production.

METHODOLOGY FOR ANALYSIS OF POTSHERDS

This study involves several methods for the purpose of field data collection. The main method used is the excavation to collect evidence of potsherds to conduct quantitative and scientific analysis. After the sample was obtained, quantitative analysis was conducted first to obtain basic information on the typology of the potsherds. After the quantitative analysis, scientific analysis of XRD, XRF and SEM were made on the potsherds samples. The scientific analysis results was compared with the results of the analysis of soil samples taken in the ancient river at the Sungai Batu Archaeological Complex. This was to resolve issues related to local or foreign raw materials have been used in the process of producing potsherds.

QUANTITATIVE ANALYSIS OF POTSHERDS FROM THE SUNGAI BATU ARCHAEOLOGICAL COMPLEX

Quantitative analysis of potsherds samples involved determination of weight, thickness and types of debris; either representing part of the lip, body or pottery base following classification determined by Rice (1987) and Nurhadi *et al.* (2008). The analysis for thickness is divided into three categories: 1) for less than 6 mm, 2) medium, for between 6-10 mm and 3) for thickness more than 10 mm. From the results of the study on 15 potsherds, the type of pottery classification is determined to be body (Plate 1) (nine pieces (60%)), lip (Plate 2) (three pieces (20%)) and base (Plate 3) (three pieces (20 %)). The thickness analysis of pottery fragmentation clearly illustrates that the pottery thickness at the river jetty and administrative sites is moderate, between 6-10 mm (Table 2). The thickness suggests its use for food preparation or for other daily use.

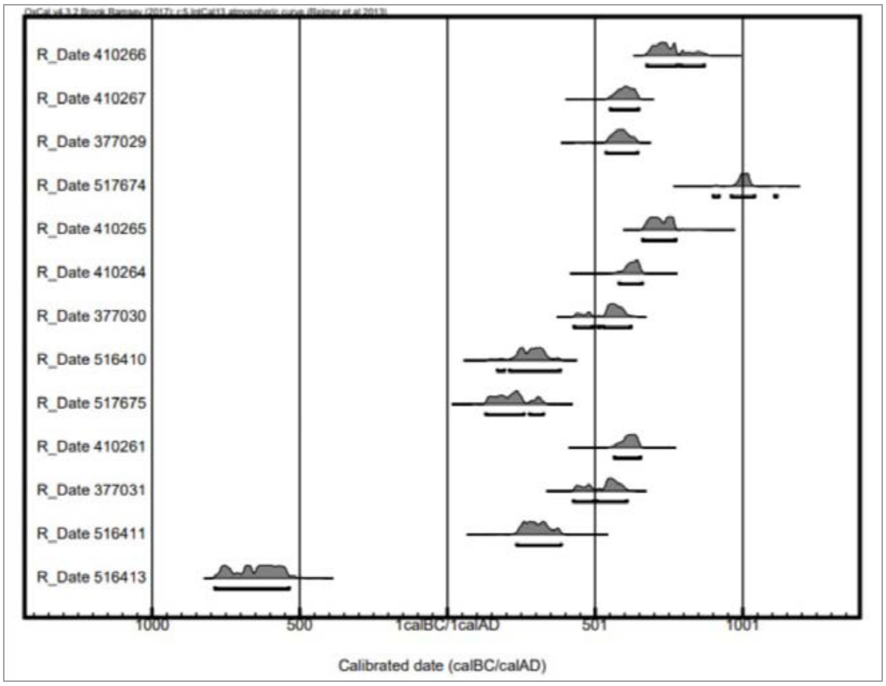

Figure 2: Chronological model of Site SB2H.

Plate 1: Classification of body part of fragmented potsherd found at river jetty and administrative sites.

Plate 2: Classification of lip part of fragmented potsherd found at river jetty and administrative sites.

Plate 3: Classification of base part of fragmented potsherd found at river jetty and administrative sites.

Table 2: The results of the quantitative analysis of pottery samples at river jetty and administrative sites at Sungai Batu Archaeological Complex.

No. Sample	Thickness (mm)	Weight (g)	Color	Section
1	9.46	34	7.5YR 7/8 Reddish Yellow	Body
2	9.81	28	7.5YR 8/4 Pink	Body
3	9.43	46	7.5YR 7/4 Pink	Base
4	7.62	16	7.5YR 7/4 Pink	Base
5	9.45	31	7.5YR 7/3 Pink	Lip
6	9.93	14	7.5YR 7/6 Reddish Yellow	Lip
7	8.17	21	7.5YR 7/4 Pink	Body
8	5.04	17	7.5YR 5/3 Brown	Body
9	8.73	27	7.5YR 7/4 Pink	Body
10	8.66	38	7.5YR 6/3 Light Brown	Body
11	9.07	13	7.5YR 6/2 Pinkish Gray	Lip
12	8.66	16	7.5YR 5/3 Brown	Base
13	8.04	25	7.5YR 5/3 Brown	Body
14	8.89	14	7.5YR 5/3 Brown	Body
15	9.04	19	7.5YR 5/3 Brown	Body

The analysis also attempts to identify the potsherds' colors using Munsell Soil Color Charts. From the study, at least five colors were identified for potsherds found at the river jetty and administrative sites, which are reddish yellow, pink, brown, light brown and pinkish gray. According to Chia (1997), potsherds with these colors are commonly found in Peninsular Malaysia. Further, according to Chia (1997), the yellow-colored potsherds is also a clear indication that it was burned at an optimum temperature that allows oxidation to occur perfectly. This clearly illustrates that the society had been able to regulate the temperature of the combustion to produce quality potsherds Before Centuries.

The quantitative analysis of the 15 pieces of potsherds also revealed it originated from pottery without decorations. This is because on the body, base and lip parts of the potsherds, cord-marked, impressed, incised, circle, punctated and displacement technique are not detected. This find indicates a different type of potsherds than those found in Kuala Selingsing, Sungai Mas and Pengkalan Bujang, which revealed decorations on the potsherds (Ahmad Fawzi, 1986). Based on potsherds typology, this strongly suggests that the process of potsherds making at the Sungai Batu Complex was at an early stage and did not involve any form of beauty of appearance in its potsherds. This is because the ornamental patterns on potsherds represent the custom and growing artistic style of the time.

XRD, XRF AND SEM ANALYSIS OF POTSHERD SAMPLES

The results of XRD analysis on potsherd samples (Table 3) clearly reveal the presence of quartz and montmorillonite minerals that dominate the pottery samples. In addition, quartz, microline, rutile, zircon, anatase and muscovite were also detected in the pottery. Based on the presence of montmorillonite and illite minerals in the pottery samples, it is suggested that burning was at temperatures around 550 °C up to 650 °C, as suggested by Zuliskandar *et al.* (2008) and Palanivel & Rajesh (2011). Based on the scientific analysis, the results strongly suggest the possibility of open firing techniques being applied during the potsherds kiln process. This interpretation is submitted because burning the potsherds does not require high temperatures.

From the XRF analysis, the main and trace element contents detected are silica (SiO_2), aluminum (Al_2O_3) and iron oxide (Fe_2O_3) between 69.05%, 13.31% and 5.13% (Shamsul Anuar, 2015) (Table 4). The high silica content obtained through this XRF analysis has amplified the XRD analysis results that revealed silica as the dominant content in potsherds samples. This is reinforced based on the SEM analysis that shows the wide range of sand content including circles and squares (Plate 4). In addition, the presence of aluminum (Al_2O_3) is similar to the presence of montmorillonite elements i.e. clay minerals which is the main raw material in potsherds production.

The CaO graph against K_2O plotted based on the XRF analysis (Figure 3) clearly shows that the source of the raw material for the process of potsherds production was taken from the same source material. The analysis results of 17 soil samples from the Sungai Batu Archaeological Complex also clearly revealed the presence of kaolinite and quartz or montmorillonite and quartz and silica

Table 3: Results of XRD analysis of potsherd samples.

No. Sample	Mineral Content	
	Mineral Name	**Chemical Name**
1	Quartz Montmorillonite	SiO_2 $Na\ O_3\ (Al, Mg)_2\ Si_4\ O_{10}\ OH_2\ 6H_2O$
2	Quartz Montmorillonite Microcline	SiO_2 $Na\ O_3\ (Al, Mg)_2\ Si_4\ O_{10}\ OH_2\ 6H_2O$ $(K_{95}\ Na\ O_5)\ Al\ Si_3\ O_8$
3	Quartz Muscovite Montmorillonite Rutile	SiO_2 $(K, Na)\ Al_2\ (Si\ Al)_4\ O_{10}\ (OH)_2$ $Na\ O_3\ (Al, Mg)_2\ Si_4\ O_{10}\ OH_2\ 6H_2O$ TiO_2
4	Quartz Montmorillonite Microcline	SiO_2 $Na\ O_3\ (Al, Mg)_2\ Si_4\ O_{10}\ OH_2\ 6H_2O$ $(K_{95}\ Na\ O_5)\ Al\ Si_3\ O_8$
5	Quartz Muscovite Montmorillonite Microcline	SiO_2 $(K, Na)\ Al_2\ (Si\ Al)_4\ O_{10}\ (OH)_2$ $Na\ O_3\ (Al, Mg)_2\ Si_4\ O_{10}\ OH_2\ 6H_2O$ $(K_{95}\ Na\ O_5)\ Al\ Si_3\ O_8$
6	Quartz Muscovite Montmorillonite Microcline	SiO_2 $(K, Na)\ Al_2\ (Si\ Al)_4\ O_{10}\ (OH)_2$ $Na\ O_3\ (Al, Mg)_2\ Si_4\ O_{10}\ OH_2\ 6H_2O$ $(K_{95}\ Na\ O_5)\ Al\ Si_3\ O_8$
7	Quartz Montmorillonite Microcline	SiO_2 $Na\ O_3\ (Al, Mg)_2\ Si_4\ O_{10}\ OH_2\ 6H_2O$ $(K_{95}\ Na\ O_5)\ Al\ Si_3\ O_8$
8	Quartz Microcline Montmorillonite Anatase	SiO_2 $(K_{95}\ Na\ O_5)\ Al\ Si_3\ O_8$ $Na\ O_3\ (Al, Mg)_2\ Si_4\ O_{10}\ OH_2\ 6H_2O$ TiO_2
9	Quartz Microcline Montmorillonite Anatase	SiO_2 $(K_{95}\ Na\ O_5)\ Al\ Si_3\ O_8$ $Na\ O_3\ (Al, Mg)_2\ Si_4\ O_{10}\ OH_2\ 6H_2O$ TiO_2
10	Quartz Montmorillonite Rutile Zircon	SiO_2 $Na\ O_3\ (Al, Mg)_2\ Si_4\ O_{10}\ OH_2\ 6H_2O$ TiO_2 $Zr\ O_2$
11	Quartz Microcline Montmorillonite	SiO_2 $(K_{95}\ Na\ O_5)\ Al\ Si_3\ O_8$ $Na\ O_3\ (Al, Mg)_2\ Si_4\ O_{10}\ OH_2\ 6H_2O$
12	Quartz Illite Montmorillonite Rutile	SiO_2 $(K, H_{30})\ Al_2\ (Si_3, Al)\ O_{10}\ (OH)_2\ xH_2O$ $Na\ O_3\ (Al, Mg)_2\ Si_4\ O_{10}\ OH_2\ 6H_2O$ TiO_2
13	Quartz Montmorillonite Microcline	SiO_2 $Na\ O_3\ (Al, Mg)_2\ Si_4\ O_{10}\ OH_2\ 6H_2O$ $(K_{95}\ Na\ O_5)\ Al\ Si_3\ O_8$
14	Quartz Muscovite Montmorillonite Microcline	SiO_2 $(K, Na)\ Al_2\ (Si\ Al)_4\ O_{10}\ (OH)_2$ $Na\ O_3\ (Al, Mg)_2\ Si_4\ O_{10}\ OH_2\ 6H_2O$ $(K_{95}\ Na\ O_5)\ Al\ Si_3\ O_8$
15	Quartz Montmorillonite Microcline	SiO_2 $Na\ O_3\ (Al, Mg)_2\ Si_4\ O_{10}\ OH_2\ 6H_2O$ $(K_{95}\ Na\ O_5)\ Al\ Si_3\ O_8$

(Table 5). Based on the match of the analysis, it clearly illustrates that the raw material for the manufacture of potsherds was taken in the vicinity of Sungai Batu itself. This is because kaolonite originates from the granite rocks located in the vicinity of Mount Jerai (Bradford, 1972) while montmorillonite was derived from the shale rocks in Sungai Petani Formation (Bradford, 1972; Burton, 1988). This area is close to the study area based on the geological map.

The results of the trace element analysis showed that the lead content (Pb) in potsherds was low which strengthened the interpretation that it was produced using local material. This is because the potsherds analysis from India has recorded high lead content, as suggested by Zuliskandar *et al.* (2001). This enabled the interpretation that the potsherds found in the river jetty and administrative sites were made using the raw material in the vicinity of Sungai Batu.

Table 4: Results of XRF analysis of potsherd samples.

Content (%)	Sample No.				
	1	**2**	**3**	**4**	**5**
SiO_2	65.06	62.22	60.02	60.30	64.56
Ti_2O	0.91	0.91	0.92	1.17	0.90
Al_2O_3	18.60	18.08	18.55	20.16	18.07
Fe_2O_3	4.01	5.95	6.40	3.70	3.59
MnO	0.01	0.01	0.01	0.01	0.01
MgO	0.80	0.76	0.63	0.23	0.69
CaO	0.06	0.05	0.04	0.06	0.09
Na_2O	0.14	0.14	0.13	0.10	0.12
K2O	1.04	1.02	0.99	0.80	0.96
P_2O_5	0.04	0.03	0.04	0.05	0.03
	6	**7**	**8**	**9**	**10**
SiO_2	62.69	68.73	61.23	67.51	59.89
Ti_2O	0.89	0.87	0.82	0.82	1.04
Al_2O_3	17.67	16.78	18.30	17.92	20.79
Fe_2O_3	5.79	2.55	5.79	3.02	4.94
MnO	0.01	0.01	0.12	0.01	0.01
MgO	0.74	0.66	0.89	0.77	0.28
CaO	0.07	0.03	0.05	0.04	0.04
Na_2O	0.15	0.11	0.15	0.11	0.12
K_2O	0.99	0.93	0.91	1.00	1.05
P_2O_5	0.03	0.03	0.04	0.03	0.05
	11	**12**	**13**	**14**	**15**
SiO_2	59.95	59.56	59.90	63.17	64.15
Ti_2O	0.96	1.06	0.93	1.10	0.92
Al_2O_3	19.67	19.26	19.15	21.96	18.74
Fe_2O_3	5.85	6.33	5.21	1.83	3.56
MnO	0.01	0.01	0.01	0.01	0.01
MgO	0.60	0.25	0.66	0.25	0.56
CaO	0.04	0.06	0.04	0.04	0.06
Na_2O	0.13	0.15	0.12	0.07	0.13
K_2O	0.89	1.06	0.92	0.87	0.91
P_2O_5	0.04	0.04	0.05	0.03	0.03

Table 5: Raw data of soil samples from the Sungai Batu Comples taken for XRD analysis.

No. Sample	Content	Location of Sampling	No of Sampling
1	Kaolinite and quartz	Ancient river near jetty site SB1K	3
2	Kaolinite, montmorillonite and quartz	Ancient river near jetty site SB1J	3
3	Kaolinite and quartz	Ancient river near administrative site SB1M	3
4	Kaolinite and montmorillonite	Ancient river near jetty site SB2B, SB2D and SB2E	5
5	Kaolinite and montmorillonite	Ancient river near administrative site SB2ZZ	3

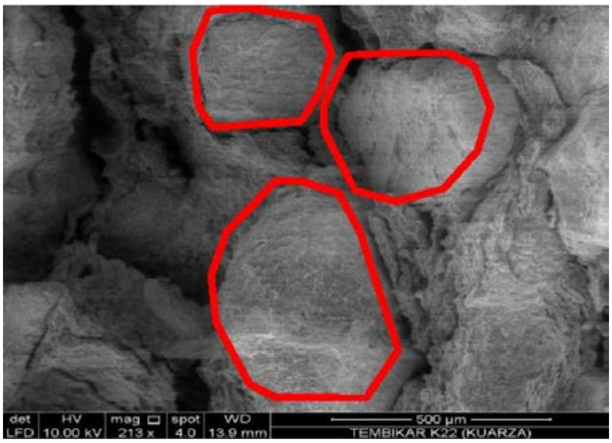

Plate 4: The SEM analysis results show the size of sand (red circle) that reinforces XRD and XRF analysis data related to the use of silica as the raw material in potsherds (after Shamsul Anuar, 2015).

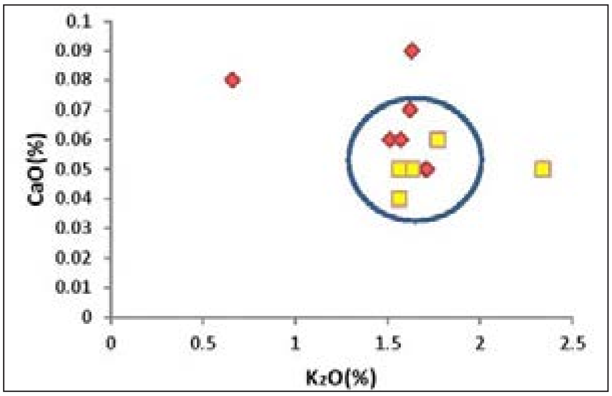

Figure 3: CaO graph against K_2O for potsherds. It is clearly shown that the raw material was taken from the same area in Sungai Batu (after Shamsul Anuar, 2015).

CONCLUSION

The results of XRD, XRF and SEM analysis clearly reveal the raw material of potsherds found at the jetty and administrative sites in the Sungai Batu area. This is suggested based on the presence of quartz and montmorillonite minerals as the dominant minerals, and the presence of low lead (Pb) elements which differed from the analysis of imported potsherds that have high lead elements. The results of soil sample analysis illustrate that the basic ingredients for pottery making was taken around the Jerai and Mahang formations near the Sungai Batu site. The results of potsherd analyses in the Sungai Batu area have reinforced the analysis of the local material as the main medium for pottery production in Sungai Bujang, Sungai Baru, Mukim Merbok, Mukim Bujang and Sungai Merbok Kecil (Zuliskandar *et al.*, 2014).

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Study on beneficiation of silica sand by Wet High-Intensity Magnetic Separators (WHIMS) and reverse flotation technique for glass application: A case study from Sihanoukville, Cambodia

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Abstract: White silica sand samples were collected from Steuong Hav district area. The samples were mixed and quartered to obtain a representative sample for physical and chemical characterization. Silica (SiO_2) and iron oxide (Fe_2O_3) content were measured by X-ray fluorescence (XRF) analysis. The results showed silica and iron oxide content at 94.83 wt.% and 0.189 wt.% representatively. In this study, a shaking table, Wet High-Intensity Magnetic Separators (WHIMS), and reverse flotation technique was undertaken to remove mainly iron oxide. The collectors amine (named AOA) and petroleum supinate (named NANZA), pine oil as frother, and H_2SO_4 as depressant were used to optimize the froth performance. The iron oxide content was removed from 0.189wt.% to 0.062 wt.% and the silica content was upgraded from 94.83 wt.% to 98.6 wt.% after the process.

Keywords: WHIMS, reverse flotation technique

INTRODUCTION

Silica sand is one of the essential natural material resources, which is commonly used as an ingredient in many industries such as glass, bottle, construction, ceramic and other chemical industries. The most influencing factors to the properties of glass are iron impurity, the particle size, and mineral phase during the melting process, which affects the clarity and quality of the produced glass. A typical impurity in silica sand concentrate is iron oxide (Fe_2O_3) which can usually be removed using chemical or physical process (Sereiratana *et al.*, 2013). The content of iron oxide impurity in silica sand can affect the optical properties of the glass. For example, with higher Wt. % of iron oxide, the colour of the glass produced will be brown or green (bluish-green). According to the British Standard BS29875, the standard for glass manufacture is based on allowable impurities. There are 5 out of 7 standards which is the highest grade for glass application: grade A: optical glass, SiO_2 = 99.5 %, Al_2O_3 = 0.2%, and Fe_2O_3 = 0.013%. B: tableware glass, SiO_2 = 99%, Al_2O_3 = 0.2%, and Fe_2O_3 = 0.01%. C: borosilicate glass, SiO_2 = 98.5, Al_2O_3 = 0.2%, and Fe_2O_3 = 0.01%. D: colorless glass, SiO_2 = 98.8, Al_2O_3 = 0.1%, and Fe_2O_3 = 0.03% (Marzia Hoque, 2014; Platias *et al.*, 2014).

Impurities in glass sands are usually present as free and coated iron oxide, clay, titanium and refractory minerals. Iron is the most harmful impurity. It can be reduced by physical, physicochemical or chemical leaching methods, depending on the real condition of the mineral form (Ibrahim *et al.*, 2013).

The measurement of separation and iron oxide removal efficiency follows PerkinElmer atomic absorption (Hacifazlioglu, 2014).

$$\eta(\%) = \left| 1 - \frac{\alpha_i}{\alpha_f} \right| \times 100 \qquad \text{Equation 1}$$

Where α_i = iron oxide content in concentrate
α_f = iron oxide content in the feed

While the liberated impurity can be reduced or removed by using physical operation such as shaking table (spiral concentrate is more efficiency liberated) and WHIMS etc., some bearing iron content cannot be removed with these processes, such as titania oxide, ilmenite, and other iron oxide still contained in the final product of the physical process. This study focused on impurities removal from silica sand to meet the specification of colourless glass industry by using physical and physicochemical processes (reverse flotation).

MATERIAL AND METHODOLOGY

Sample preparation

The sand sample used in the experiment was taken from Steung Hav district, Cambodia. The sample was taken at a depth of 2 m. Eight samples were taken to represent many areas, named P34, P40, P46, W5, W7, W11, W27 and W28. They consisted iron oxide ranging from 0.12-0.29 Wt.% with an average of 1.89 wt.% and silica oxide ranging from 91.5-98.28 wt.% with 94.7 wt.% as an average value, as shown in Table 1. The chemical composition of the material was analyzed using X-ray fluorescent. The particle size distribution was investigated using sieve analysis method. Only grain size less than 20 mesh was used in this study.

Experiment

This study was conducted with a physical and physicochemical method to remove the iron oxide from sand to meet the specification of grade D of the standard glass manufacture, as shown in Figure 1.

This experiment was conducted on a laboratory scale. Samples received from the field was directly dried at 115°C for 24 hours to determine the particle size using sieve analysis, and followed by wet sieve to reject the particles with size greater than #20 mesh (841 µm). The samples was subjected to shaking table (ST) (Wilfley model) with 8, 10, 12, and 15 degrees of inclination to figure out the effect of each inclination to the removal of iron oxide to determine the optimised condition for further experiments (Ibrahim *et al.*, 2013). All compositions were checked through the Wavelength Dispersive X-Ray Fluorescence Spectroscopy (WDXRF) machine. Then, the products from the ST were transferred to the attrition scrubber using the Denver Flotation machine for cleaning the surface of the particles with 60% solid. In this case, the optimization of the attrition process was applied by studying the effect of impeller speed, and time of scrubbing before we directly put it in WHIMS with the magnetic current at 14 Amp. The wet processing using WHIMS involves two coils of magnetic forces. There many factors effecting this process, such as form of matrix, feed rate, water flow rate, rinse water and magnetic field intensity. As the feed pulp passed through the matrix, magnetic particles are held on to the matrix field while non-magnetic particles go through to be collected (Haniza & Idham, 2014).

Reverse flotation was conducted using WEMCO flotation cell with a capacity of 4L. To remove impurities from silica sand to meet the specification of colorless glass, the promoters chemical name AOA (named by a local company in Thailand, which is an amine, a cation collector), and NANZA (petroleum supinates, anion collector), and pine oil as a frother collector as depressants (Win, 2015) were used. The representative sample from the WHIMS process ranged from 700-1000 g of each condition within 4000 ml slurry sample in the flotation cell. In this experiment, eight conditions ware carried out to get the optimization condition for further experimentation. AOA and NANZA solution used was in the range from 40 and 50 ml. While the speed of agitator was 1200 rpm, and sulfuric acid H_2SO_4 solution 20 ml regulary with pH value of 1-2.

Table 1: Chemical composition of original sand sample.

SAMPLE ID	SiO_2	Al_2O_3	Fe_2O_3	ZrO_2	TiO_2
P34	98.28	0.26	0.16	0.04	-
P40	95.8	2.1	0.18	0.05	0.22
P46	94.86	1.94	0.26	0.05	0.14
W5	91.5	4.06	0.29	0.05	0.25
W7	92.3	4.58	0.23	0.06	0.32
W11	93.4	2.59	0.14	0.19	0.53
W27	94.8	3.07	0.14	0.05	0.2
W28	96	2.46	0.12	0.04	0.17
Mean	94.61	2.63	0.19	0.06	0.26
Median	94.83	2.52	0.17	0.05	0.22
Min	91.5	0.26	0.12	0.04	0.14
Max	98.28	4.58	0.29	0.19	0.53

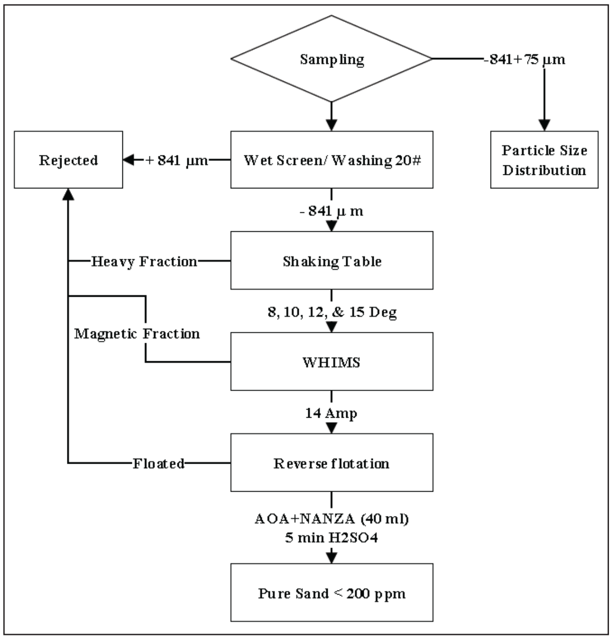

Figure 1: The flowchart of this study.

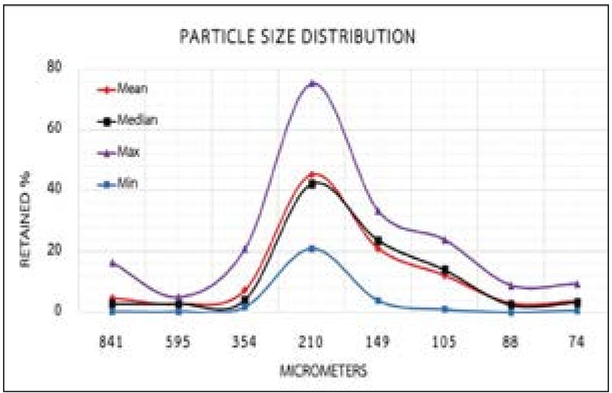

Figure 2: Particle size distribution.

RESULT AND DISCUSSION

Sample characteristic

The result of particle size distribution presented as 200 g of silica sand check through the dry sieve analysis within aperture range from 0.841 mm, 0.6 mm, 0.425 mm, 0.212 mm, 0.15 mm, 0.106 mm, and 0.075 mm within 20 minutes. After rejecting particles +0.85mm fraction, the sample size is commonly ranging from -0.425mm to + 0.106mm. From the XRF analysis, the composition of Al_2O_3 (0.26-4.5%), Fe_2O_3 (1.89 -0.286 wt. %) and SiO (91.5-98.8) was obtained. For raw silica sand as shown in McLaws (1971), it is classified as high-grade silica sand, based on the component SiO_2 = 99 wt. % (Ibrahim *et al*., 2013). In Figure 3, the impurities in raw silica sand which is associated with siliceous during the geological weathering process of sands can be noted.

Shaking table

This experiment was conducted with various deck inclinations, such as 8, 10, 12 and 15°, with water flowrate of 0.22 l/s. The representative sample was 1 kg of each condition. The process of shaking the table was performed until having no middling fraction or less amount, then repeated for 5 times of middling fraction. With the frequency of shaking around 276 rpm, it has created a length of stroke 10 mm in order to do a pretreatment of purities in silica sand. From the result of the previous condition, it is shown that the highest removal of iron oxide occured when the deck is inclined at 12°, shown in Figure 4. When the inclination is increased to 15°, the percentage of iron removal gradually decreased from 72.11% to 58.78%. Thus, the suitable condition of the shaking table is 12° with an acceptable yield percentage of 93.71 %.

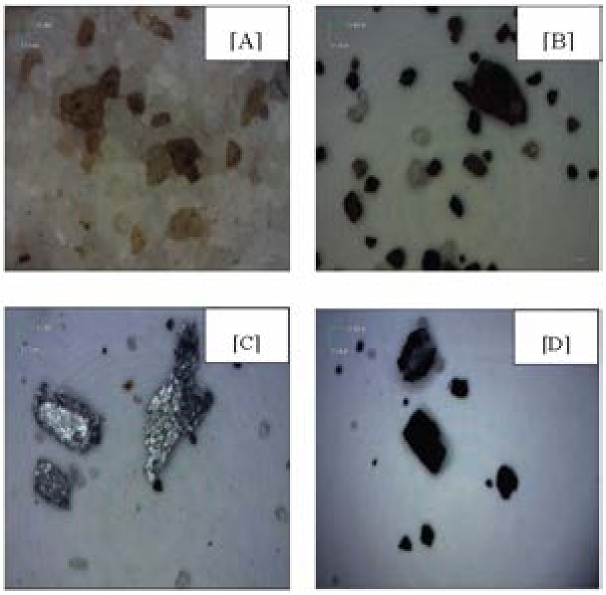

Figure 3: [A] quartz and garnet, [B] tourmaline and hematite, [C] alumina oxide, [D] ilmenite.

Wet high-intensity magnetic separator

The second step of physical treatment was conducted using a Wet high-intensity magnetic separator (WHIMS) to reach the requirement of a high grade sand. The result showed a significant change from the shaking table, siliceous increased from 96.6 wt.% to 98.5 wt.%, and iron oxide gradually decreased from 0.09 wt.% to 0.06 wt.%, which is represented by iron removal (64.78%) and the yield percentage reached 99% (Figures 6 and 7).

Reverse flotation

The third process, reverse flotation, is a physicochemical method to remove the iron oxide as the physical methods

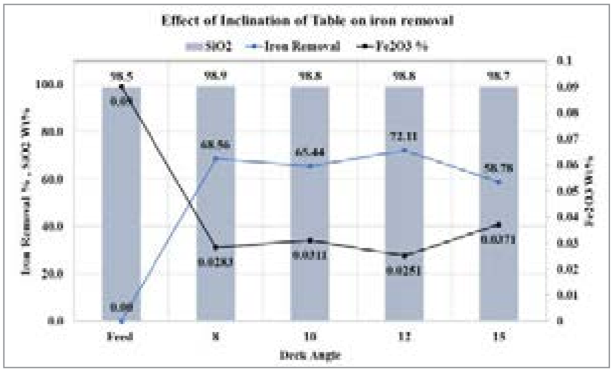

Figure 4: Effect of deck inclination of shaking table.

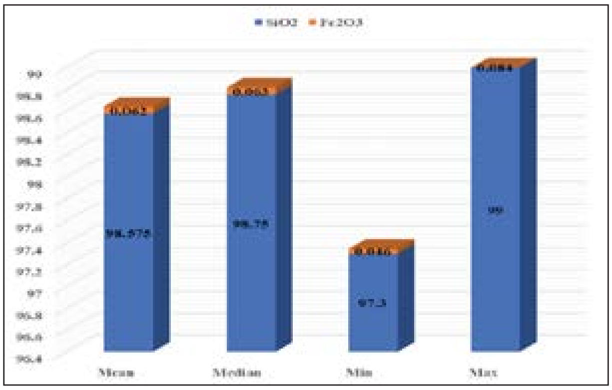

Figure 5: Result of XRF.

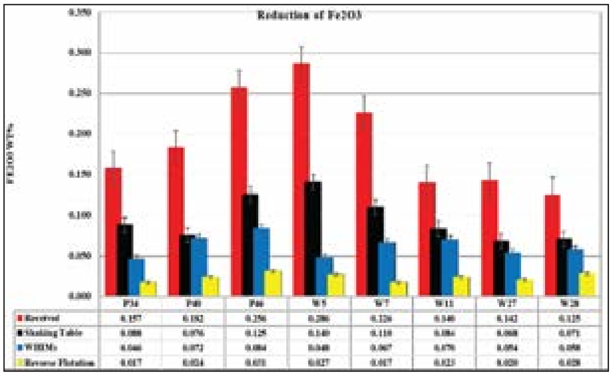

Figure 6: Significant removal.

could not achieve the target of grade D glass. The results showed that the siliceous content increased from 99.03 wt.%, and iron oxide was reduced from 0.06 wt.% to 0.023 wt.%, with an average removal percentage value of 86.77%. As mentioned earlier, this silica grade can be considered as a very pure silica sand, after going through the third treatment process. The chart in Figure 9 shows the significant reducing of iron oxide from the original sample to the final product.

CONCLUSION AND RECOMMENDATION

The experiment was conducted at a laboratory scale using the shaking method with 12° deck angle and has highly removed the iron oxide. Moreover, the physicochemical method of reverses flotation with some parameters consumption of collector AOA+NANZA = 40 ml, acid sulfuric 20 ml, and pine oil 0.1 ml can further remove the iron oxide to 86.7%. The wet high-intensity magnetic separator followed by reverse flotation is a high performance in terms of iron oxide removal, but it could be a costly operation due to the collector and acid demand. Therefore, further researches would be conducted with the spiral gravity and followed by WHIMS to optimize the cost of processing.

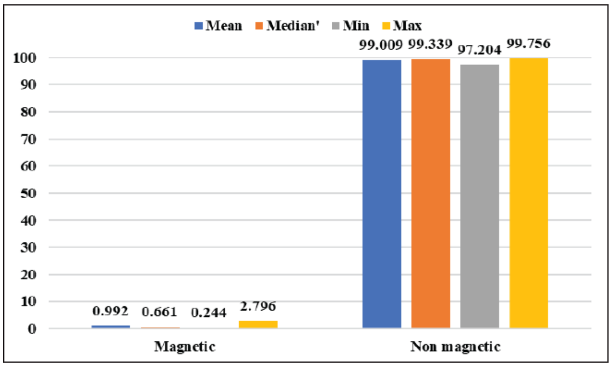

Figure 7: Yield percentage from WHIMS process.

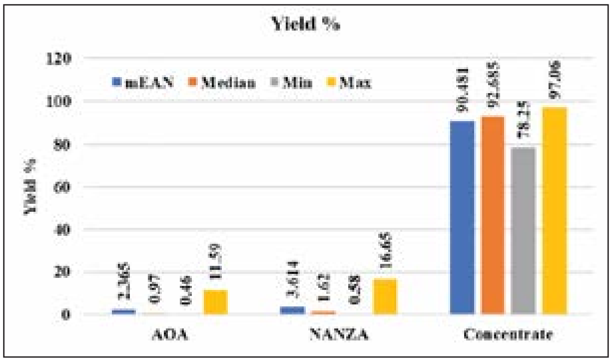

Figure 8: Yield percentage of reverse flotation.

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Variation in textural properties of aplitic kaolin from Kinta Valley

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Abstract: Textural properties are among one of the fundamental characteristics especially important to be understood before suitable application(s) of a kaolin can be determined as they have direct influence on the other properties such as plasticity, brightness, firing and rheological behavior. This paper presents an investigation on the textural properties of aplitic kaolin from Kinta Valley. Two degritted kaolin samples from different location of Kinta Valley were measured for their particle size distribution by laser diffraction method. The samples were then classified into different size fractions followed by examination of their morphological property by various techniques which X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR) and field emission scanning electron microscope (FESEM). Generally, the kaolin can be classified into two different types based on the fine fraction content which may be consists of; i) delaminated platy kaolinite, or ii) tubular shaped halloysite. These fine fractions however constitute only to minor amount or not more than 12 % of the clays, as both clay consist predominantly of coarse book like kaolinite stacks. The degree of crystallinity of kaolinite samples shows a positive correlation to its particle size during examination by XRD, but FTIR spectrum shows a high degree of crystallinity for all kaolinite samples regardless of their particle size. Slight presence of halloysite is sufficient to give an adverse effect on the clay crystallinity index measured from XRD pattern. Sorting of the clay into different size and morphological fraction creates a product with less variation in properties between individual particles, and with more potential for tailoring or engineering of their properties.

Keywords: Kaolin, soft kaolin, kaolinite, halloysite, texture, textural properties, crystallinity index

INTRODUCTION

Kaolin minerals are hydrous phyllosilicate mineral form with the formula of $Al_2Si_2O_5(OH)_4$ (Newman & Brown, 1987). A single unit structure of kaolin mineral is formed by stacking of one silica tetrahedral sheet onto one aluminum hydroxide octahedral sheet (Al-Shameri & Rong, 2009). Kaolin has a wide range of industrial applications due to the unique characteristics it possesses (Murray, 2000). The major consumers of kaolin included the paper, paint, rubber, plastic, ceramic, refractory and glass fibre industry (Siddiqui *et al*., 2005; Sengupta *et al*., 2008). Kaolin also find its applications in production of Portland cement, pesticides, and pharmaceutical products (Aras *et al*., 2007). The applicability of kaolin into these fields however depends largely on the physio-chemical properties of kaolin which can vary significantly according to their origin and parent material (Wilson & Jiranek, 1995; Varajao *et al*., 2001; Sayin 2007; Masoud *et al*., 2013; Yuan *et al*., 2014; Gina *et al*., 2020). Textural properties are among one the fundamental properties especially important to be understood as they have direct influence on the other properties related to the applications of kaolin such as plasticity, brightness, firing behavior and rheological properties of kaolin. The texture of a clay material refers to the particle size distribution of the constituents, the particle shape which is related to the morphology, the orientation of the particles with respect to each other, and the forces which bind the particles together (Murray, 2007). In this paper, two of the important physical aspects (particle size and morphology) which define the texture of clay will be examined. The importance of particle size distribution and the particle shape to the properties of clay with kaolinite as its major components had been emphasized by Murray (2000). Systematic and proper characterization of the particle size and morphology of kaolin is necessary to enable better understanding on the behavior of the clay.

Morphology and shape of kaolin

In nature, kaolin may be encountered in different morphological form other than kaolinite such as halloysite, nacrite and dickite (Senoussi *et al*., 2016). Kaolinite, nacrite and dickite has very similar crystal structure and differs from each other by the ordering pattern of vacant octahedral site in subsequent layers (Bailey, 1980). Halloysite on the other hand is formed by rolling of a planar 1:1 layer (Bailey, 1990). The layer curls with the tetrahedral sheet on the outside of the curve to minimize the misfit of the larger tetrahedral and smaller octahedral sheets (Singh & Mackinnon, 1996). The crystal morphologies of kaolin particles should be accurately identified as it has a large effect on the possible application of kaolin. Plasticity of clay is related to the morphology of the plate-like clay mineral particles that slide over the others when water is added (Ryan & Radford, 1987). Tube like halloysite particles are unsuitable for coating application due to the adverse effect on rheological properties they provide to kaolin even if they presence only in minor amount, but can be utilized for more advanced application as catalyst, adsorbent and carrier at molecular level (Yuan *et al*., 2015). However, uses of kaolin are very limited if kaolinite and halloysite are found to co-exist. The only known application of halloysite-kaolinite mixture are utilized for ceramic and porcelain production (Churchman *et al*., 2016). Degree of crystallinity is an alternative method to explain the morphology of clay minerals, although they cannot provide direct information on the texture of the clay. Higher degree of crystallinity signifies a clay with coarser particle sizes and is commonly associated to soft kaolin where the composition is dominated by book like kaolinite stacks (Kogel *et al.*, 2006). Poor crystallinity index indicates the presence of fine kaolinite or halloysite (Brindley, 1980).

Particle size distribution

The particle size distribution also influences the physical and optical properties of the clay. Particle size distribution is a major factor controlling the ceramic behavior of a clay which included the plasticity, shrinkage and strength after drying and firing (Ryan & Radford, 1987). The brightness, opacity or hiding power which is affected by the degree of light scattering in the clay is a function of the particle size distribution. In term of ceramic properties, body formed by coarser particles usually has a lower shrinkage after firing or drying but is associated with a lower flexural strength due to the higher porosity of the ceramic body (Wilson, 2004). Fine and platy kaolinites with size finer than 2 μm are the major material responsible for the plastic behaviour (Andrade *et al*., 2011).

PROBLEM STATEMENT AND OBJECTIVE

The most well-known and established kaolin producing region in Malaysia is located at the Bidor-Tapah area of Perak state. Kaolin from the area have a long history of being examined by various researchers (Aw, 1983; Liew *et al*., 1985; Aw, 1986; Baioumy, 2012; Cheang *et al*., 2013). The kaolin from Kinta Valley however had not received as much attention as the above kaolinitic occurrence. Although it had been studied by few researchers (Arrifin *et al*., 2008; Baioumy, 2012; Chin *et al*., 2017), no in-depth investigation on the textural properties of the kaolin from Kinta Valley had been provided. This paper is aimed to report and discuss the textural variation of aplite derived kaolin from East Kinta Valley.

METHODOLOGY

Two degritted kaolin originated from different location from East Kinta Valley labelled as SA and SC are selected for this study. Particle size analysis by laser diffraction method with the instrument Malvern Mastersizer 2000 is first adapted to determine the quantity of fine fraction in each material. The next step involve extraction of < 2 μm fraction through decantation technique. The clay is first mixed in distilled water in the ratio 1:5, followed by dispersion using ultrasonic bath for 5 minutes. Calgon is added into the suspension in an amount of 0.1 % to the weight of clay to assist the deflocculation of the clay particles. The < 2 μm fraction is then extracted as the suspension located above 5 cm from the bottom of the clay suspension container after allowing the coarser particles to settle for 24 hours. The given settling time is computed according to Stokes' law. The collected suspension containing the fine and coarse fraction after separation are then dried at 105 ºC and pulverized into powder form for subsequent analyses. It must be emphasized that the clay should be pulverized gently to prevent any alteration or destruction of original clay morphology from excess grinding (Sánchez-Soto *et al.*, 2000; Ding *et al*., 2012). The morphological variation between the raw material, fine fraction and coarse fraction are then observed under scanning electron microscope (ZEISS Gemini 500). Identification of clay and determination of crystallinity of different size fraction are also performed using Fourier transform infrared spectroscopy (FTIR) (Perkin-Elmer) at the scan range of 4000 cm^{-1} – 400 cm^{-1} and X-ray diffraction scanning (XRD) (Bruker D8 Advanced) is performed at the scan range of 5 º2θ – 70 º2θ. The crystallinity index is computed from the XRD pattern according to the method proposed by Hinckley (Kogel *et al*., 2006).

RESULT AND DISCUSSION

Particle size distribution (PSD)

The result of PSD analysis is tabulated into Figure 1. Clay SA and SC has an average particle diameter of 20 μm and 11 μm respectively. The < 2 μm fraction of both clay constitutes to only 9 %vol and 12 %vol composition in SA and SC respectively. The clays are exceptionally coarse, thus failed to meet the specification of commercial kaolin for coating and filler applications which require 15 % – 92 % of < 2 μm fraction (Siddiqui *et al*., 2005). Locally, the clay has particle size coarser than the kaolin from Bidor-Tapah area with an average content of 42.5 % of < 2 μm fraction (Cheang *et al*., 2013).

Scanning electron microscope (SEM)

SEM images supported by the particle size analysis reveal that for both materials are principally the soft

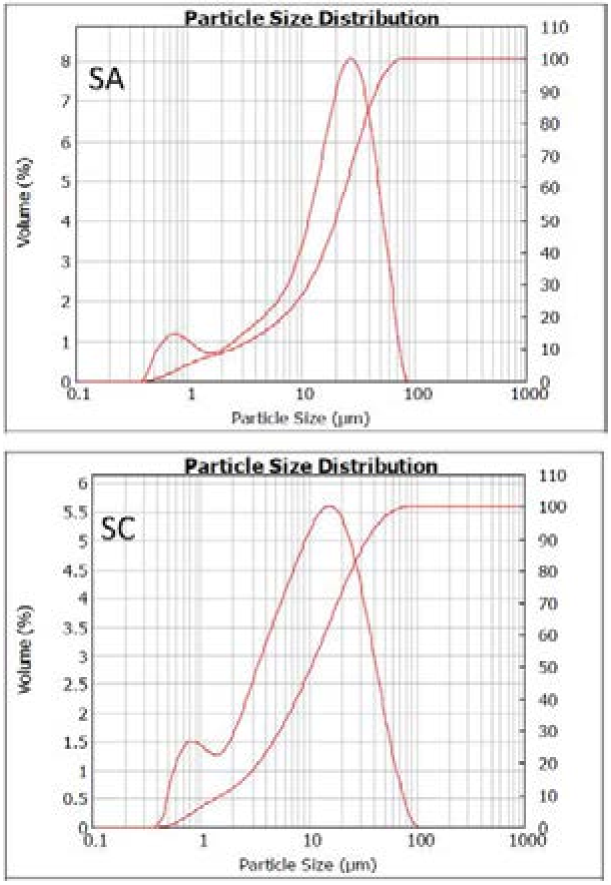

Figure 1: Particle size distribution of processed clay from samples SA and SC.

kaolin type dominated by coarse book like kaolinite stacks (Pruett, 2016). SA consists of mixture of halloysite and book like kaolinite as in Figure 2(a), while SC is the typical soft kaolin type made up of fine platy kaolinite and coarse kaolinite stacks as shown in Figure 2(b). Decantation had efficiently classified the clay into two fractions based on their size. Clay SA had it finer tube like halloysite particles separated from the book like stacks of kaolinite as shown in Figure 2(c). Sample SC on the other hand had the finer delaminated platy kaolinites separated from the coarse kaolinite stacks as shown in Figure 2(d).

X-ray diffraction (XRD) pattern

The 7.0Å basal peak of kaolin minerals are observable from all samples in Figure 3 (Masoud *et al.*, 2013). Poorer resolution for the pair of triplets perceived at the scan range from 34 °2θ - 40 °2θ is observed following the increases of fine fraction in for both sample SA and SC. Removal of -2 μm fraction from SC increased the Hinckley crystallinity index from 0.52 to 0.74 where the clay is promoted from the category of poorly crystallized to well crystallized kaolinite. Halloysite containing clay displays a broad asymmetrical peak with more weight at the lower angle covering 20 °2θ – 23 °2θ, rendering the computation of crystallinity index impossible. Halloysite presence in slight amount is sufficient to cause the -50 μm fraction from SA to displayed a poorly resolved diffraction pattern similar to the solely halloysite containing -2 μm

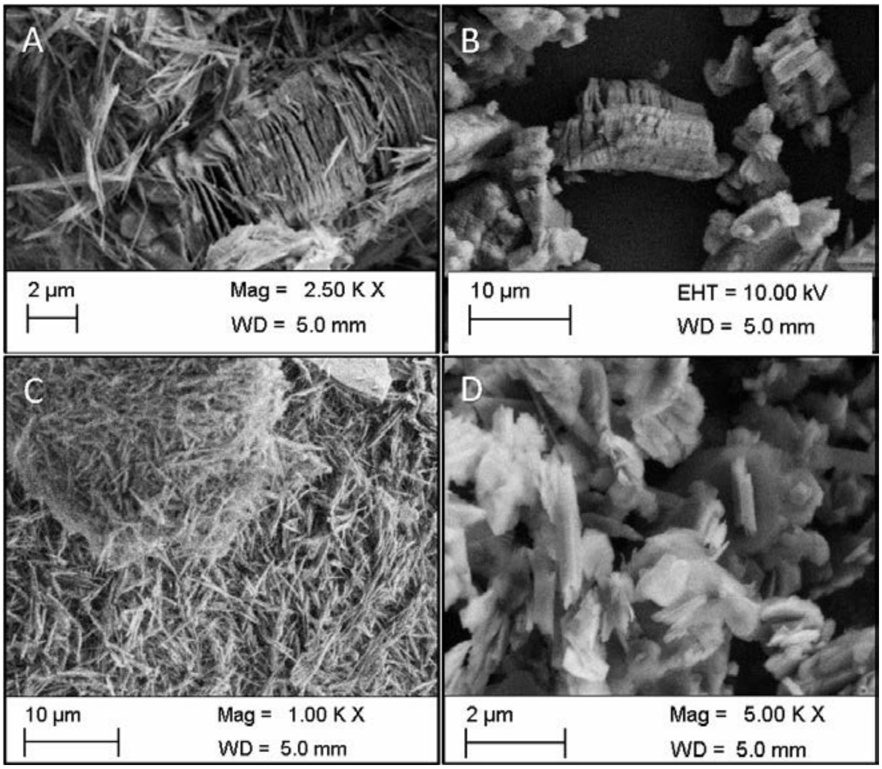

Figure 2: SEM images of processed aplitic kaolin. (A) Halloysite-kaolinite mixture from SA. (B) Platy and stacked kaolinite from SC. (C) Tubular halloysite separated from SA by decantation. (D) platy fine size kaolinite separated from SC by decantation.

fraction from SA. Halloysite shows a more deteriorate effect to the crystallinity displayed on the diffractogram of kaolinite compare to platy kaolinite as demonstrated by comparing XRD pattern of -50 µm fraction of SA to SC, although both are expected to exist as highly disordered crystallites (Brindley, 1980). The +20-50 µm fraction from SA shows a crystallinity index of 0.86 which is categorized as well crystallized kaolinite after the interference of halloysite is eliminated.

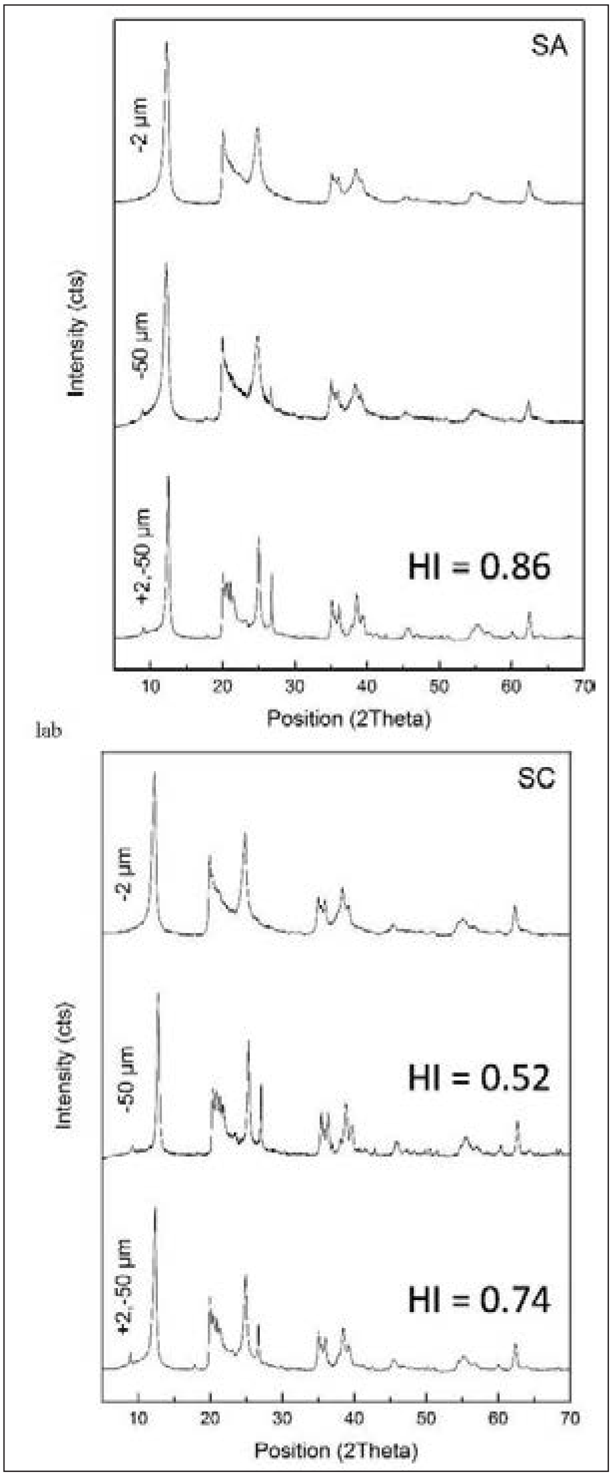

Figure 3: X-ray diffraction pattern of different sized fraction clay from SA and SC. -50 µm = original degritted clay, -2 µm = clay fraction obtained from decantation, -2 +50 µm = coarse settled fraction from decantation. HI = Hinckley crystallinity index.

Fourier transform infrared spectroscopy (FTIR)

Degritted clay samples displayed the typical kaolinite hydroxyl stretching absorption bands at the position of 3696 cm^{-1}, 3672 cm^{-1}, 3650 cm^{-1} and 3622 cm^{-1} (Figure 4). These four sharp and well resolved peaks indicate a high degree of structural order for all these kaolinite samples (Brindley *et al*., 1986). After the classification by size, all kaolinites samples still displayed four highly resolved absorption peaks at the range of 3700 cm^{-1} – 3620 cm^{-1}. On the other hand, the solely halloysite containing sample

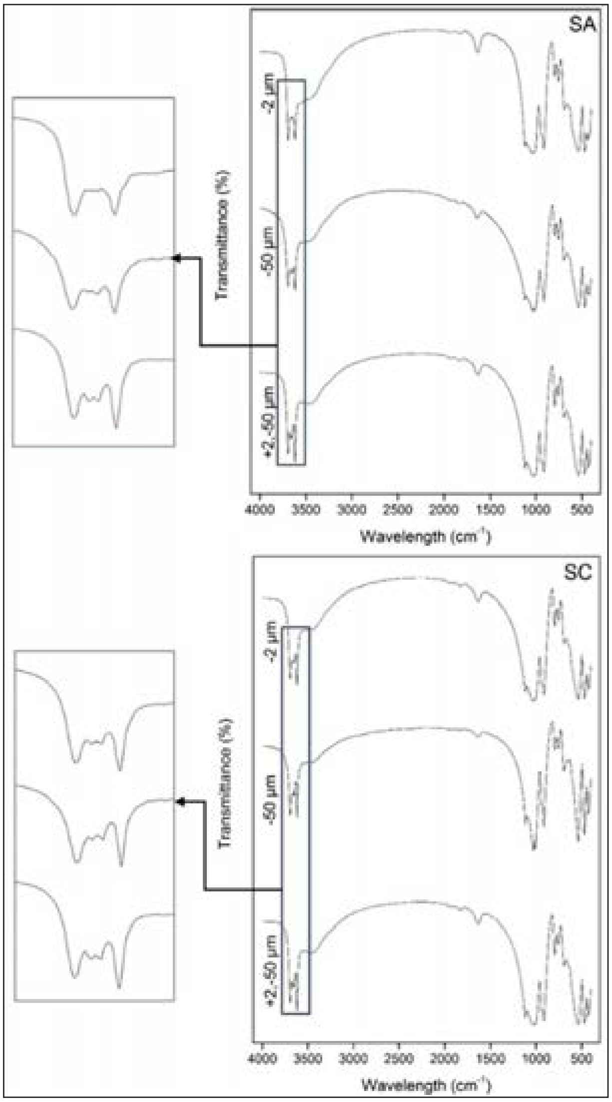

Figure 4: Infrared transmittance spectrum of different sized fraction clay from SA and SC. -50 µm = original degritted clay, -2 µm = clay fraction obtained from decantation, -2 +50 µm = coarse settled fraction from decantation.

shows a poorly resolved pattern at this scan range that is similar to the absorption spectrum of highly disordered kaolin. The OH-bending absorption bands which kaolin clay exhibits at 938 cm^{-1} and 915 cm^{-1} (Ekosse, 2005) are visible for all samples, except the halloysite containing samples which included the -50 µm and +2, -50 µm fraction from SA which displayed an inflexion point instead of a peak at 938 cm^{-1}. The weak doublets with about equal transmittance at 795 cm^{-1} and 758 cm^{-1} is another feature to distinguish well crystallized kaolinite from halloysite (Vaculíková *et al*., 2011). Unlike the diffractogram by XRD method, the high crystallinity kaolinite stacks are observed to play a major role in the affecting the FTIR spectra. Sample SA which consists of kaolinite and halloysite mixture shows four well resolved peak at the range between 3700 cm^{-1} – 3620 cm^{-1}.

CONCLUSION

The textural and morphological properties of aplitic kaolin had been successfully investigated and characterized using PSD and SEM techniques. The kaolins are principally the soft type where coarse kaolinite stacks contribute to the major composition. The kaolin however can be classified into two types based on the morphology of finer particles which may be consists of: i) delaminated platy kaolinite, or ii) tubular shaped halloysite. These fine fractions however constitute only to minor amount or not more than 12 % of the clays. Both clay consist predominantly of coarse book like kaolinite stacks. The degree of crystallinity of kaolinite samples shows a positive correlation to its particle size when examined by XRD, but the FTIR spectrum shows a high degree of crystallinity for all kaolinite samples regardless of their particle size. Slight presence of halloysite gives an adverse effect on the crystallinity determined from XRD. Sorting of the clay into different size and morphological fraction creates a product with less variation in properties between individual particles, and with more potential for tailoring or engineering of their properties.

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Groundwater potential assessment using 2-D resistivity method in Kluang, Johor (Malaysia)

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Abstract: Sources of clean water are decreasing due to rapid usage, contaminated surface waters, pollution and dry season. The dependence on the existing water source is not enough to fulfil the increasing demand of population in Malaysia. In order to overcome the problem, groundwater source is the most suitable alternative. 2-D resistivity method was carried out in a granitic area of Kluang, Johor to delineate and locate groundwater resource. 5 survey lines were conducted by using ABEM SAS4000 terrameter and electrode selector which were connected to 41 electrodes through lund cables. Pole-dipole array was chosen in this study for deeper penetration. Collected data were processed by using RES2DINV software to produce inversion model which was then exported to Surfer8 software for visualisation and interpretation. The result shows that most of the study area consist of granite with different level of fracturing. Unconfined aquifer was found at depths of 0 to 50 m. Confined aquifers can be seen at two different zones. They exhibit same properties at three parallel lines, R1-R3 and show continuity between them. It is predicted that the aquifers flow in the southwest to northeast direction. The hard rock aquifers are highly recommended to be drilled as they contain a large amount of fresh water for further usage.

Keywords: Groundwater, 2-D resistivity, granite, confined aquifer

INTRODUCTION

Water is an important element in life because it is used on a daily basis, including industries and agricultures who utilize water in large amount. A growing population has increased clean water demand. The existing clean water sources which mostly originates from surface water is decreasing due to unplanned waste system which has led to pollution of rivers, streams and lakes. During the dry seasons, the amount of rainfall is reduced, simultaneously reducing the amount of water accumulated. Hence, a need for a new water source arises.

Groundwater poses as an alternative in fulfilling the urgent water demands as it is safe from pollution and of high quality water (Anomohanran, 2015). Groundwater exploration in other developed countries are very common but less conventional in Malaysia due to high dependence on surface water. Groundwater in the subsurface is present in either unconfined or confined aquifers. Aquifers are saturated zones of water filling pore spaces, fractures and cracks in the subsurface.

Drilling wells into an unconfined aquifer creates problems due to over pumping of the aquifer where the withdrawing rate is faster than the rate of water recharging. This leads to declination of existing water table and groundwater quantity. Empty pore spaces due to absence of water may cause land subsidence to occur (Changming *et al*., 2001). Aquifers near the coastal areas are inclined towards seawater intrusion because of the hydraulic connection of ground and sea waters (Al-Naeem, 2014). This intrusion causes the water from the aquifer to be unsuitable for drinking purpose. Unconfined aquifer is also susceptible to pollution problems as it is connected to surface water. Contaminated water bodies that seep through the soils will carry impurities into the subsurface, subsequently polluting the groundwater. These problems must be overcome to improve water management in this country. Hence, confined aquifer is an imperative solution for clean water resource as the water is safe from pollution and is unconnected to potentially contaminated surface water (Smith *et al.*, 2013). When a well is drilled into a confined aquifer, the water will automatically flow upward under influence of high pressure of the subsurface. Hence, no pump is needed thus saving expenses (Encyclopedia Britannica, 2015; Lutgens *et al*., 2015). The deep aquifer is also unaffected by seasonal changes, making it vital for clean water source of all time.

Groundwater specifically confined aquifer can be investigated by using common geophysical and geotechnical techniques such as resistivity, seismic refraction, vertical electrical sounding (VES), induced polarization (IP), GIS, remote sensing, self-potential, gravity, ground penetrating radar (GPR) and boring. The most qualified way in delineating groundwater potential is electrical resistivity method because it is economical and effective (Anomohanran, 2013). This technique is able to map resistivity distribution of the subsurface, estimate aquifer properties and classify resistivity of different lithologies effectively (Sirhan *et al*., 2011; Majumdar & Das, 2011; Ewusi *et al.*, 2009). The objective of this study is to predict groundwater potential in Kluang, specifically confined aquifer with correlation to the geology of the area and generate useful information that can be used for groundwater exploration in the future.

STUDY AREA

The study took place in Kluang, the central district of Johor, Malaysia. It is located at Utm coordinate of 2.076° N, 103.374° E, about 8 km from the nearest main town, Bandar Kluang (Figure 1). This study covered 200,000 m^2 area. Geomorphologically, this area is surrounded by palm oil plantations where some parts have been cleared. Industrial factories and main road can also be found nearby. The study area is elevated about 40 m to 70 m from sea level in the northwest towards southeast direction. The geology of Kluang consists of sedimentary rocks which come from the Semberong Ridge of Jurassic to Cretaceous age. The rocks are dominated by mudstone, siltstone, sandstone and partly tuffaceous (Said *et al*., 2003). The study area however is located within undifferentiated acid intrusive region close to the border of the sedimentary formation, as shown in Figure 2. This site was chosen for study of groundwater occurrence in a granite setting which is expected to take place through discrete fractures that act as a secondary porosity (Misstear *et al.*, 2017). The topsoil is dominated by clay and sand as observed in the vicinity.

METHODOLOGY

A total of five survey lines were successfully conducted in the study site. Three of the lines were designed parallel to each other in a northwest-southeast orientation with a gap of about 80 m between them while the other two lines cut across them perpendicularly to cover the area as much as possible within a considerable period. R1 – R3 were conducted by implementing the roll-along method (Dahlin, 2001). R1 survey line consists of 3 spreads of 400 m length, overlapped for every 200 m, making the total length 800 m and it is the same for R3. While R2 consists of 2 overlapped spreads. The lines were designed to observe any significant changes between them and predict the groundwater flows. The study was done by employing 41 electrodes that were planted firmly on the ground to ensure good quality data acquisition of the subsurface true resistivity (Soupios *et al*., 2007). The electrodes were connected to electrode selector and ABEM SAS4000 terrameter through lund cables in straight lines with a constant spacing of 5 m. Pole-dipole electrode arrangement was chosen in this survey because it can penetrate deeper compared to other arrays, which is useful for mapping subsurface at great depth for groundwater exploration (Loke, 1999). The collected data were processed using RES2DINV to produce true resistivity subsurface images. Then, the result was exported to Surfer8 software to produce contour maps for a better presentation and a clearer perspective of the subsurface. Table 1 provides a standard resistivity value of different types of soils and rocks for reference.

Figure 1: Location of study area showing electrical resistivity lines (Google Earth, 2017).

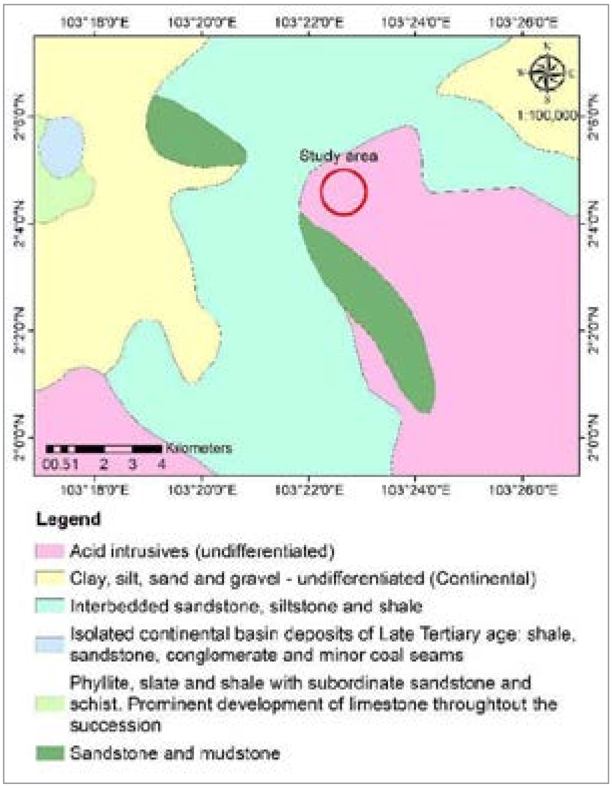

Figure 2: Regional geology map of Kluang (Mineral & Geoscience Department Malaysia, 1985).

Table 1: Resistivity values of common rocks and materials (Nicaise *et al*., 2012).

Material	Resistivity (Ωm)
Dry sand	1000 – 10,000
Sand saturated with fresh water	50 – 500
Sand saturated with salt water	0.5 – 5
Clay	2 – 20
Silty sand	10 – 50
Sandstone	50 – 1000
Limestone	50 – 4000
Granite, basalt	1000 – 10,000

RESULTS AND DISCUSSION

The interpretation of the results is the most crucial part to understand the subsurface. The processed data were correlated with some common rocks and minerals values to map the subsurface. However, these values might differ depending on the degree of subsurface disturbances or subsurface intermixture. For example, granitic rocks have a very high resistivity value which is above 5000 Ωm, but if many fractures are present in the rock and it is filled with water, the measured resistivity value will appear to be lower than the initial value (Loke, 1999).

Figure 3 shows the 2-D resistivity inversion of R1–R5. R1-R3 comprise of 400 m spreads, the maximum penetration depth obtained is about 160 m. The overall results show a large variation in resistivity values which indicate that the soils in the study area is not homogenous. Resistivity model of R1 shows that the subsurface is largely made up of granite. The top soil is made up of clay and alluvium materials. Granite with high resistivity values can be seen at distance 0 – 100 m and 400 – 530 m, both at depth of 0 – 100 m with resistivity value of 3000 – 20000 Ωm. A small and low resistivity area (0 – 100 Ωm) can be seen at 200 – 350 m with depth up to 50 m, most likely to be unconfined aquifer as it is shallow. The obtained values are in accordance with values reported by Nazaruddin *et al*. (2016). ‘Blue zones’ existed on this line at distance 100 – 250 m and 350 – 550 m respectively, indicated by resistivity value of 50 – 200 Ωm. These areas are distinguished as heavily fractured granite retaining waters that filled up the tiny gaps and joints inside the hard rock.

Resistivity profile R2 indicates that the topsoil composes of clay. The layer is underlain by hard rock granite with a large range of resistivity values (>3000 Ωm) near the starting point from 0 – 100 m and from 400 m towards the end of the line. The rock is dry, enabling it to retain its properties. At the center, low resistivity values can be seen at around distance of 150 – 370 m at 20 – 50 m depth, indicating the shallow aquifer. Below the aquifer is a zone dominated by weathered granite with resistivity value of 300 – 1000 Ωm. The lowest part of this line is suspected to be confined aquifer at two different distances

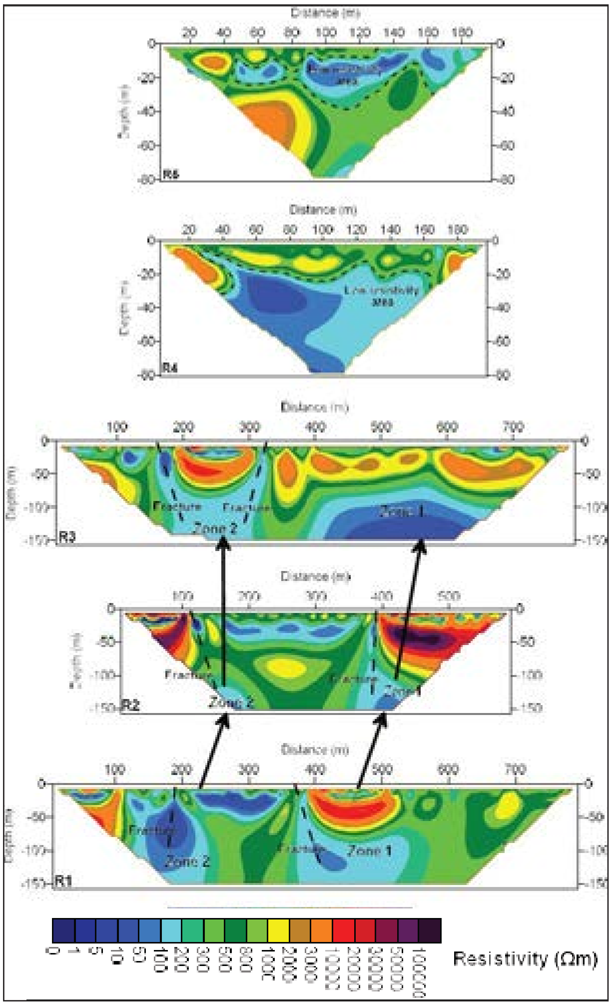

Figure 3: 2-D resistivity result of R1-R3 in Kluang.

which are 150 – 200 m and 350 – 450 m respectively. The areas are denoted by vertical and sub-vertical fractures which are favorable for groundwater movement (Sukhija *et al*., 2006). Most parts of R3 is made up of alluvium and clay underlain by weathered granite except at the distance of 200 – 300 m of this line, where an oval-shaped hard rock granite exist. At the bottom, two zones of confined aquifer can be seen, consistent with R1 an R2 lines.

The resistivity profiles R5 and R4 compliments the first 3 lines. Due to some limitations and accessibility, both lines can only be conducted for 200 m and reached a limited depth of 80 m (Cassiani *et al*., 2006). The 70 m distance of R5 crossed with 30 m distance of R2 showed a low resistivity zone. Similar subsurface features can be seen at the intersection between R5 at 140 m and R3 at 50 m. R4 model crossed R2 and R3 at 300 m, showing low resistivity zones at both lines and is consistent with the unconfined aquifer on R2. From the overall results, confined aquifer can be seen at 2 different zones which flows through lines R1 to R3. Gunung Lambak hills that is located 6 km from the study area in the southwest

Figure 4: Predicted groundwater flow.

Table 2: Generalized resistivity values in Kluang study area.

Lithology	Resistivity (Ωm)
Granite	>3000
Weathered granite	300 – 1000
Saturated fractured granite	50 – 200
Unconfined aquifer	0 – 100

direction is suspected to be the recharge area for the confined aquifer. Hence, the water movement inside the aquifer is predicted to flow from R1 to R3 (Figure 4). The hard rock aquifer is highly recommended to be drilled because they contain a large amount of fresh water that can be extracted for further usage. The overall resistivity results are classified in Table 2.

CONCLUSION

The 2-D resistivity method carried out in this study was able to locate a few potential groundwater zones including confined and unconfined aquifers in a hard rock granitic area. Both aquifers have low resistivity values due to the presence of fresh water. From the inversion model, 2 potential zones of confined aquifer can be seen flowing in a southwest to northeast direction as a sustainable potential reservoir. This survey has successfully developed an initial network of information that is essential for future water exploration in this study area on a regional scale.

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Seismic geomorphology of channels in X-Block, Penyu Basin

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Abstract: Penyu Basin is a complex, intracratonic basin, situated on the northern Sunda Shelf. This basin formed during Oligocene, and geological setting of this area is a typical Southeast Asian Tertiary rift system. An oil discovery has been made in X-Block of Penyu Basin. However, it was relinquished in 2006 due to the non-commercial oil discovery. X-Block consists of mostly monoclinal structures that do not seem to provide an efficient trapping mechanism because of the very low reliefs. Three wells have been drilled in X-Block and tested primarily on the structural traps, mainly the basement drape structures. This research aims to analyze the stratigraphic traps, focusing on channel features. This is done with the aid from seismic geomorphology. This method helps examine buried landforms by using seismic data as a tool. By seismic geomorphology study, several channel features can be recognized. Most of the channels can be found in upper and middle part of the seismic section. As going deeper to the bottom section, only lineaments of faults are visible. In the upper part of the seismic section, straight and long channel features can be observed and as moving downwards, the channel sinuosity increases resulting in meandering channel. From this seismic geomorphology study, it confirms that there are channel systems in X-Block of Penyu Basin.

Keywords: Penyu Basin, stratigraphic traps, channel-fill trap, seismic geomorphology, channel features

INTRODUCTION

Penyu Basin is an intra-cratonic basin located offshore, east of Peninsular Malaysia. Sediments in this basin were derived from the area of shallow pre-Tertiary basement to the west, generally less than 1 km thick. This research focuses on the X-Block, ca. 890 km^2, located at north-east of Penyu Basin (Figure 1).

In the early 1990's, four-fold seismo- lithostratigraphic subdivision of Penyu Basin were identified (Figure 2). The formations, in ascending order are: Penyu, Terengganu, Pari and Pilong Formation. This study targets to delineate the channels in Terengganu up to Pilong Formation. Penyu Formation consists of interbedded sandstone and shale, deposited in alluvial and lacustrine environments. During Late Oligocene, Penyu Basin subsided to about the sea level and was affected by marine incursions. This is evidenced by palynomorph assemblages in the formation, which indicates an increasing marine influence, as the basin evolved. In Miocene, Terengganu and Pari formations were deposited in alluvial and coastal plain settings. Both formations consist of mudstone/shale interbedded with fine- to coarse-grain sandstone. The Pilong Formation (youngest strata) was deposited at nearshore to shallow marine environment, and it comprises of sandstone and mudstone/shale.

Three wells (i.e R-1, R-2 and R-3) have been drilled in this area to test the basement drape structures. Oil has

Figure 1: Location of Penyu Basin (Madon & Anuar, 1999) and X-Block (marked by yellow X) (modified from ASCOPE, 1981).

been discovered in R-1, but no hydrocarbon was found at R-2 and R-3. These wells were drilled on structural targets, but the reservoirs encountered were possibly laterally discontinuous. The aim of this geomorphic

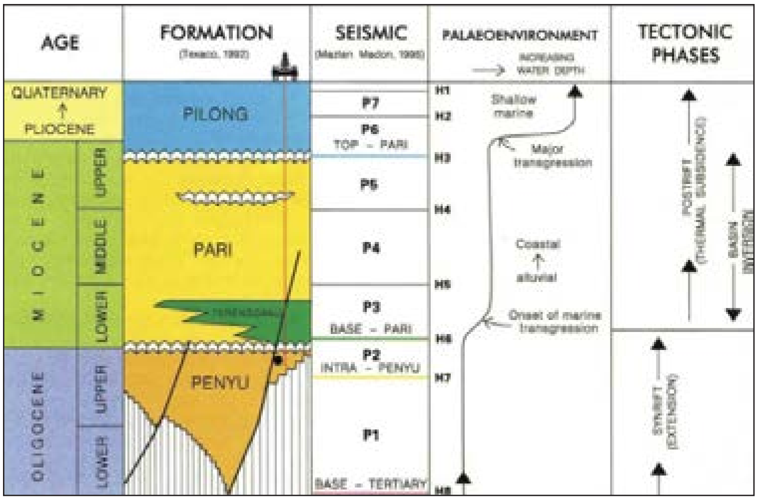

Figure 2: Stratigraphic subdivision of Penyu Basin, which consists of synrift and postrift sequences (Madon & Anuar, 1999).

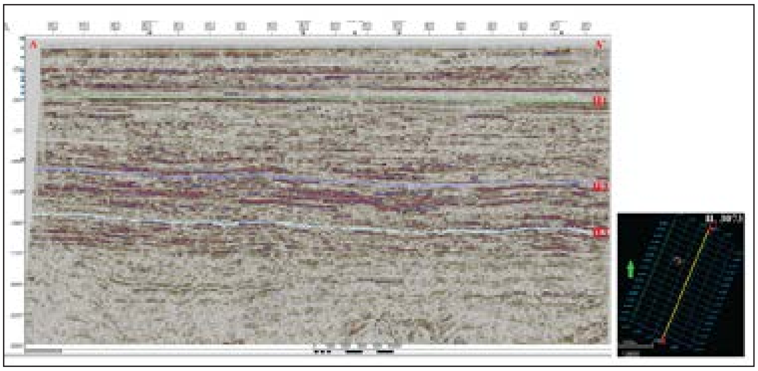

Figure 3: Horizon interpretations at inline 3073.

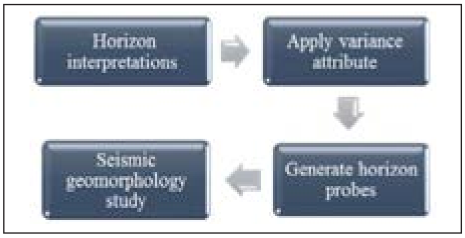

Figure 4: Workflow of study.

study is to delineate the channel systems, to support the stratigraphic distribution of the reservoir beds.

METHODOLOGY

This study is primarily based on horizons interpreted in both 3D inline and crossline, throughout the X-Block. A total of three horizons were interpreted, named as H1 (~-500 ms TWT), H2 (~-1200 ms TWT) and H3 (~1600 ms TWT), as shown in Figure 3. General method used for this study is shown in the flowchart below (Figure 4).

Variance attribute, which is an edge method is used to image the discontinuities of seismic data, which can be related to the stratigraphic lateral distribution. This attribute measures similarity of waveforms or traces adjacent over the given lateral and/or vertical windows. By that, variance attribute is a very effective tool for delineation of channel edges in both horizon slices and vertical seismic profiles. Based on the interpreted horizons, horizon probes are generated respectively to better examine any geological features. Seismic geomorphology refers to the extraction of geomorphic insights using predominantly three- dimensional seismic data, which facilitates the study of the subsurface using plan view images (Posamentier *et al*., 2007). The key in seismic geomorphology is to look for and recognize any geologically or geomorphologically meaningful patterns in plan and section views. Such patterns can take the form of fluvial or deep channels, slumps and slides or any other depositional elements as well as other geologically significant features. By using this method, seismic patterns are interpreted to determine geomorphology of a formation. This is similar to using satellite and aerial photos to portray the earth's surface (Koson *et al*., 2014). Besides, this method can also be used primarily in viewing, mapping subsurface geological features, as well as interpreting structures and stratigraphy away from well controls.

RESULTS AND DISCUSSIONS

A wide channel outline can be clearly observed in the seismic profile (Figure 5a). Horizon probe in Figure 5b, at 60 ms above H1 and 5 ms thickness, shows a relatively straight channel feature with approximately 1.5 km channel width. This channel is visually obvious and continuous as it can be seen in several vertical offsets, as the probe is moved. Several channel features can also be observed in seismic profile at the random line (Figure 6a). The channels are associated with horizon probe at 40

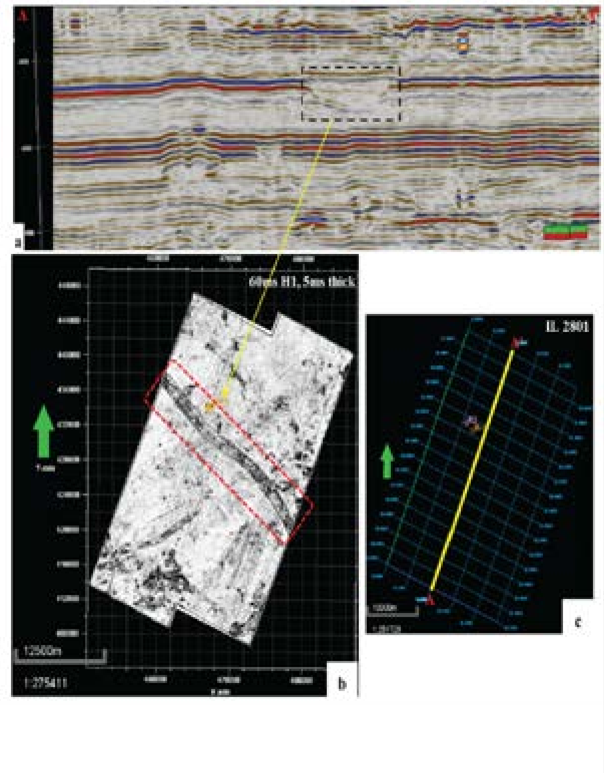

Figure 5: (a) Seismic profile at inline 2801, (b) Horizon probe at 60 ms above H1, and (c) Position of the inline.

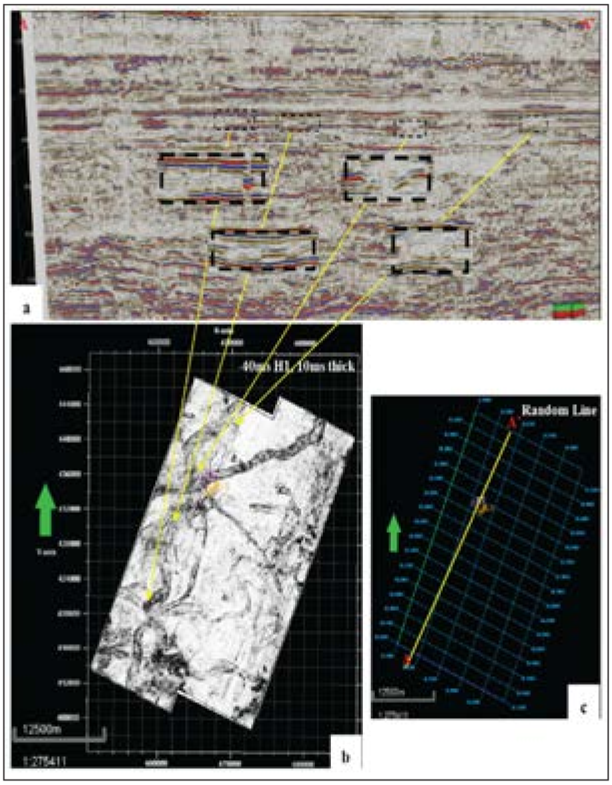

Figure 6: (a) Seismic profile at random line, (b) Horizon probe at 40 ms below H1, and (c) Position of the random line.

ms below H1, with 10 ms thickness (Figure 6b). From the probe, these channels are quite long and they overlap one another. As the probe is moved to 250 ms below H1, a very extensive channel (Figure 7b), measured at 2.8 km channel width can be observed. The seismic profile in Figure 7a also shows a big channel outline. From the profile, the inside of this channel is dominated by low amplitude responses.

Several high amplitude channel features can be identified on the seismic profile in Figure 8a. From the horizon probe at 10 ms downwards, vertical offset from H2 (Figure 8b), a clear medium-sinuosity channel can be seen. There are also several channel features observed in the surrounding area. However, these surrounding channels are not continuous and might overlap with other geological events. From the seismic profile in Figure 9a, a few small channel structures can be detected, and they show high amplitude responses. Horizon probe at -166 ms from H2 (Figure 9b) shows several small meandering, high-sinuosity channels and some of them crisscross each other. This may be due to the channels that were formed at different time intervals, thus forming the indication of stacked channels, on top of one another.

A wide channel feature, with high amplitude can be observed in seismic profile at inline 2769, as shown in Figure 10a. This channel feature is related to the horizon

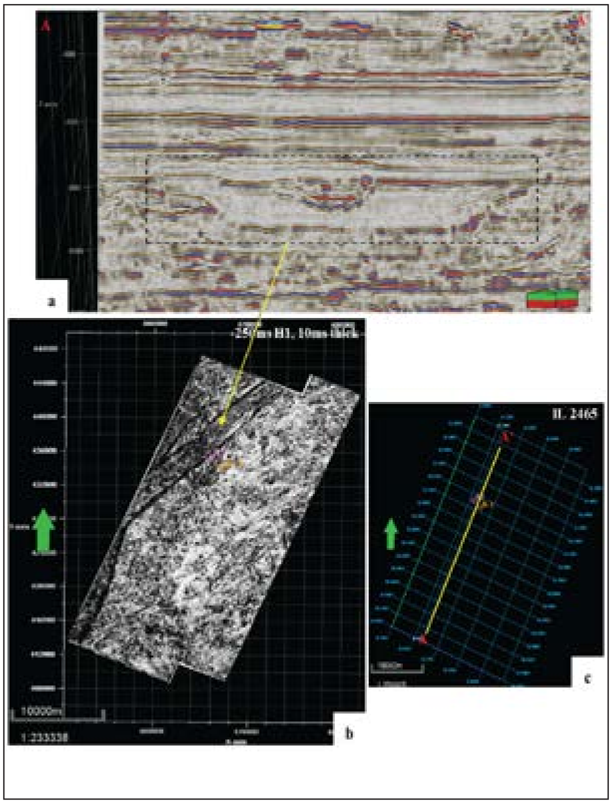

Figure 7: (a) Seismic profile at inline 2465, (b) Horizon probe at 250 ms below H1, and (c) Position of the inline.

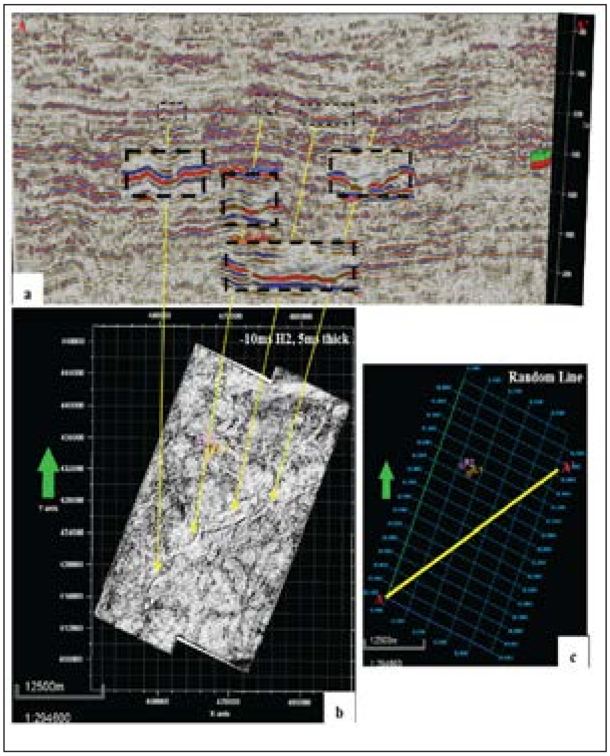

Figure 8: (a) Seismic profile at random line, (b) Horizon probe at 10 ms below H2, and (c) Position of the random line.

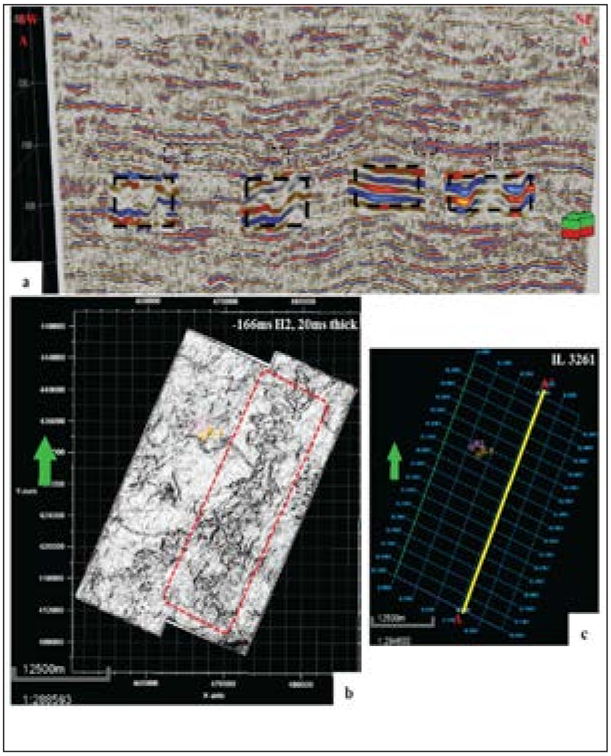

Figure 9: (a) Seismic profile at inline 3261, (b) Horizon probe at 166 ms below H2, and (c) Position of the inline.

probe at 28 ms upwards from H3 (Figure 10b). From the probe, a meander channel, almost the same result as previous probes can be detected. Besides, the edges of this low-sinuosity meandering channel are very clear and it is obvious that the channel is continuous across the study area. No other channel feature can be seen in the surrounding area of the probe. As the probe is moved further downwards from H3, for example at -255 ms from H3 (Figure 11), no more channel features can be observed. Only lineaments (highlighted by red box in Figure 11) are apparent in the probe, which might represent the faults. This is supported by numerous small faults seen in the basement on seismic section (example in Figure 12). This lack of channels in deeper strata reflects a different depositional environment.

CONCLUSIONS

Seismic geomorphology study in X-Block reveals several types of channel features, ranging from relatively straight to meandering channels with different levels of sinuosity. Numerous channel profiles can also be seen throughout the 3D seismic data in the study area. The shape of channels in seismic profiles are clear and wide, with some showing high amplitude responses. These channels are found in upper and middle part of the seismic sections. The deeper, older section only enables the delineation of faults and fracture zones from displacement of synrift systems.

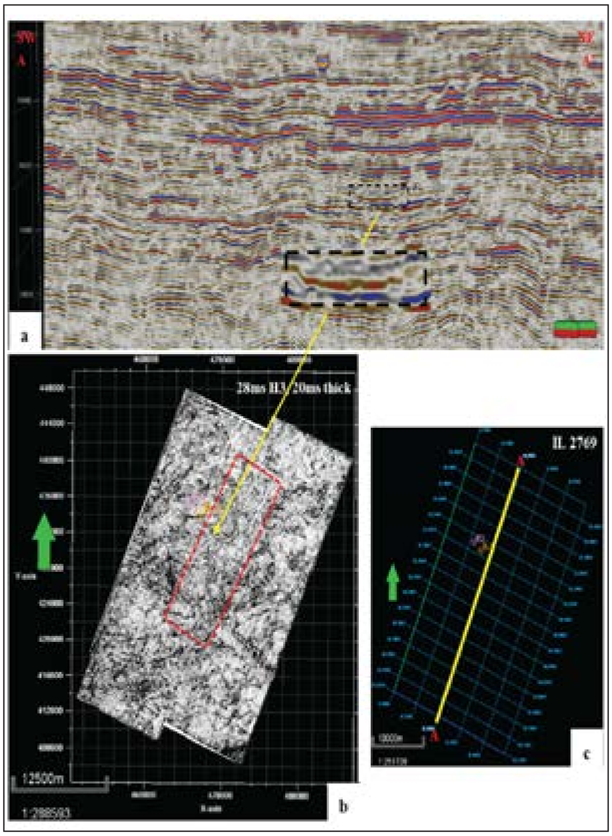

Figure 10: (a) Seismic profile at inline 2769 (b) Horizon probe at 28 ms above H3 (c) Position of the inline.

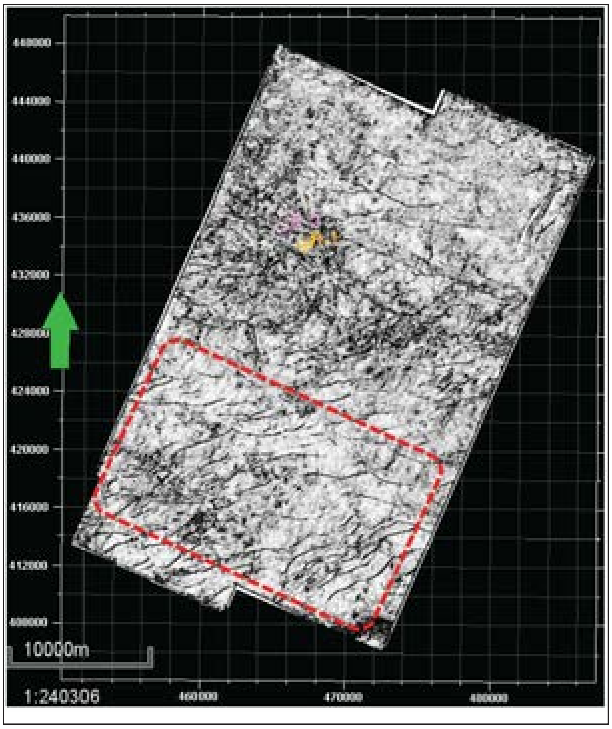

Figure 11: Horizon probe at 225 ms below H3.

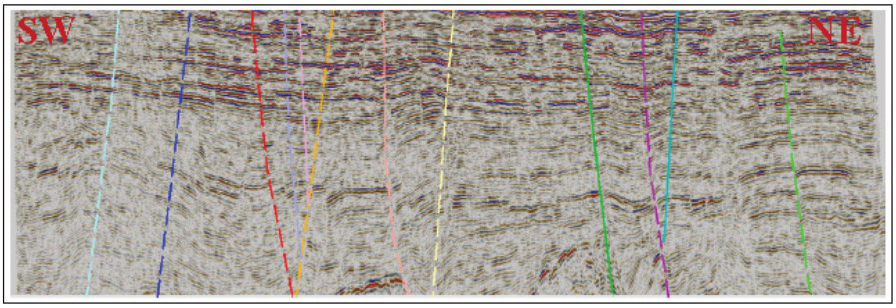

Figure 12: Some of the faults seen in basement area, example taken from inline 2869.

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High resistivity reservoirs (causes and effects): Sahara field, Murzuq Basin, Libya

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Abstract: High and low resistivity values is an alarming phenomenon that is usually associated with a very complicated reservoir history and worth looking into. Ordovician sandstone reservoirs are the primary oil producers in the Murzuq basin oil fields that is characterized with an average porosity of 14%, permeability range 410-10,760 md and clean quartz aranite composition. More than fifty wells were drilled in Sahara oil field, but only four of them were announced to have high resistivity values more than 100k ohm-m and ten others to be considered as low resistivity wells (below 50 ohm-m). Therefore, average deep resistivity was mapped in both water and oil legs using all available data set, and the top reservoir was employed as a trend map. They showed distinctive trends for low resistivity readings in oil-leg and confirmed the extreme deep resistivity nature for the wells (W7, W8, W9, and W10). Height above oil water contact and capillary pressure was also calculated for all the wells and revealed a high pressure (400 psi) at the location of the high resistivity wells. As a result, of higher capillary pressure in thicker reservoir area oil might have been able to displace water through geological time by benefitting of more considerable height above oil-water contact, higher connate pressure, and buoyancy forces support, which resulted in occupying all the larger pores and pushed the water into minor scattered pores leading to gradual alteration of reservoir wettability from water to oil-wet. Hence, the brine fluids will no longer be connected to each other inside the pore system. Therefore, they will lose their contribution to resistivity readings, and the resistivity tool will encounter a more resistant medium, which in turn will lead to underestimation of water saturation.

Keywords: High resistivity reservoirs, Upper Ordovician reservoirs, Murzuq basin, capillary pressure

INTRODUCTION

Glacial upper Ordovician sandstone formation is an excellent oil reservoir. It is located on the South Western side of the Murzuq Basin (Figure 1).

The overall reservoir thickness reaches about 400 meters. In Sahara field, extremely high resistivity intervals (more than 10,000 ohm-m) were encountered in four producing wells (W7, W8, W9 and W10) (Figure 2), while the highest resistivity recorded in the adjacent ten producing oil wells is 50 ohm-m and below. In this paper, we will attempt to investigate the causes of this event and employ it to simply and quickly uncover more complicated reservoir history, such as wettability that often needs more expensive and intense data analysis.

A reasonable core analysis program was designed by the operator to achieve a comprehensive reservoir rock characterisation. The program includes routine core analysis, special core analysis, and two wettability tests of the reservoir rocks. However, this analysis did not accurately resolve the issue of high deep resistivity variation of producing oil wells and only stated that "high resistivity due to blocky clean sandstone that might be "oil-wet". As a result, a petrophysical analysis was carried on using an average saturation exponent

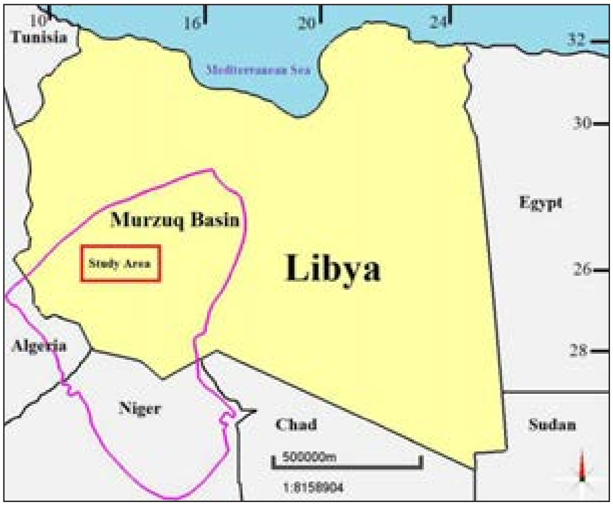

Figure 1: Location of the studied wells.

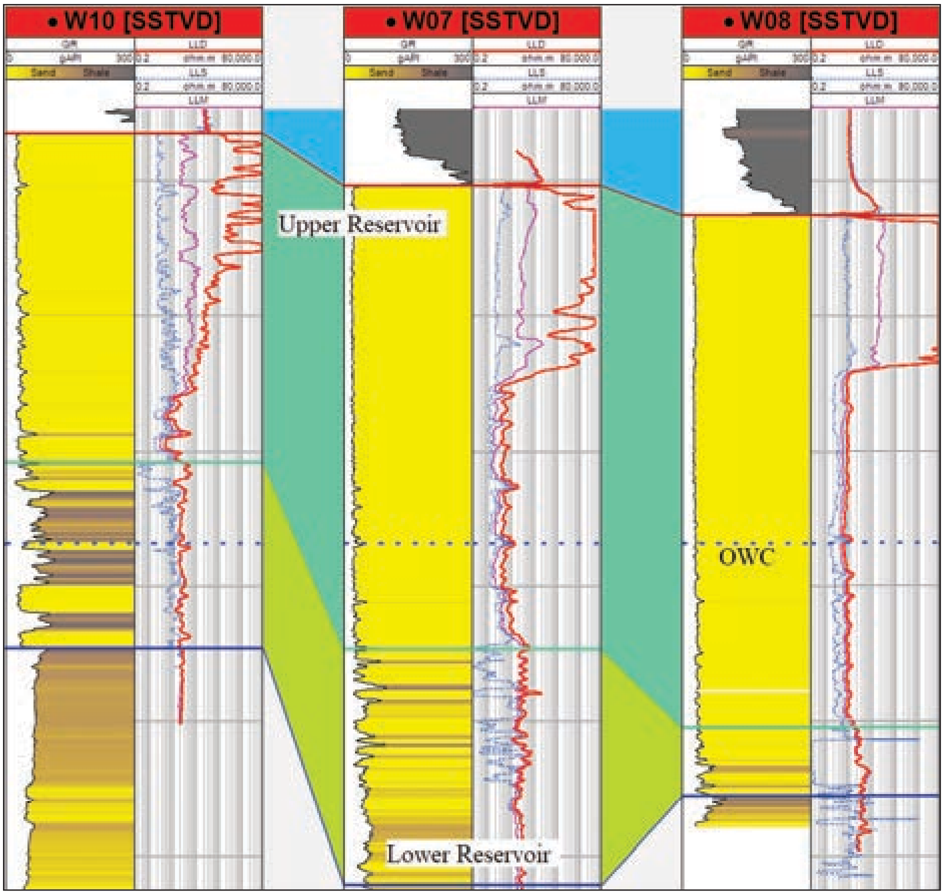

Figure 2: The main three wells with extremely high deep resistivity readings.

(n) =1.96 for all the wells, which has not been a recommended practice when dealing with an oil-wet reservoir. Where "the (n) values are found to be higher significantly than in water-wet systems" (Rust, 1957; Morgan & Pirson, 1964; Raza *et al*., 1968; Anderson, 1986a; Donaldson & Siddiqui, 1989; Gladkikh *et al*., 2005; Feng *et al*., 2016). Few years ago, Toumelin & Torres-Verdin (2005) stated that identification of reservoir wettability is made routinely on core plugs. However, there are not many published petrophysical models that practically differentiate between oil-wet and water-wet fractions of reservoir zones using commonly available log suites. Therefore, in this paper, we will be focusing on how to recognise and separate reservoir wettability fraction effects based on deep Resistivity log response and special core analysis results (SCAL).

Reservoir characterization

The reservoir rock characterization is aimed to describe the two significant elements of reservoir rock; the grains and the pore network. The measured reservoir rock parameters are primarily influenced by nature and composition of solid parts as well as the distribution of pore network. Helium porosity, horizontal and vertical gas permeability and grain density were measured using core plug samples (Figure 3). The porosity ranges from 11-21 % with an average of 15 %. The horizontal core permeability ranges between 410-190k mD.

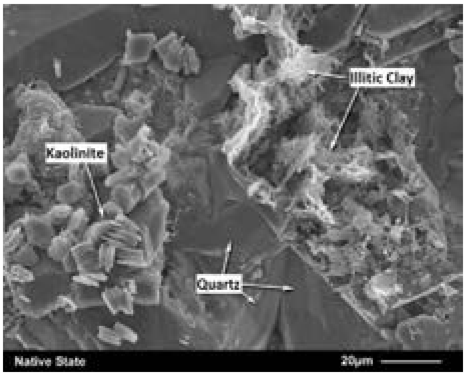

Figure 3: Main minerals identified in W7 as observed in some plugs.

Some samples were selected for petrographic description such as in Figure 3, and it concludes that the rock is mainly quartz arenite with well-sorted grain ranging in their size from 0.177-0.250 mm. The rock is mineralogically mature, dickite and kaolinite are the dominant clay mineral phase while the K-feldspar is the minor (Figure 4).

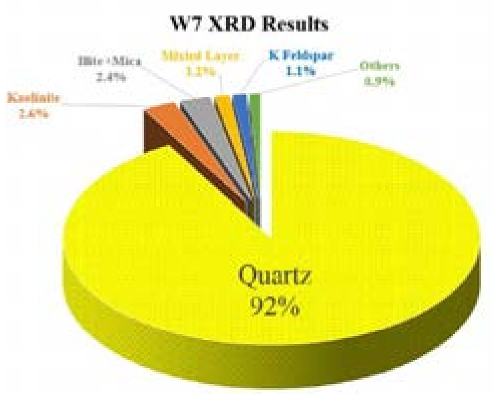

Figure 4: The main minerals identified in W7 using XRD analysis.

Wettability

Wettability is defined as the tendency of one fluid to spread on or adhere to a solid surface in the presence of other immiscible fluids (Gladkikh *et al*., 2005). The importance of wettability in reservoir rocks is that it controls the distribution of fluids within the pore network. The reservoir rocks were fully saturated with water when the rocks had been deposited. At initial conditions, the migrated oil displaced water from large pores. After the oil had been accumulated in the reservoir rocks, the water is filled small pores and form a continuous film coating the pore network. The described water saturation will render the reservoir rocks to be water-wet. Through time, if the wettability has changed to be oil-wet, the grains will be coated with oil and the water is accumulated as disconnected droplets in the centre of large pores.

Meanwhile, the small pores remain fully saturated with water. Two samples were chosen for wettability measurements. Amott method, including the static and dynamic displacement, was used to determine the wettability tendency of the reservoir rock. However, only stated neutral wet at W7 well, which is not enough.

METHODOLOGY

A detailed investigation is exclusively applied to deep resistivity data. Starting with data quality check and environmental correction using Schlumberger atlas to make sure that there was no technical error for deep resistivity readings. Then the correlation was established between high resistivity wells and normal ones to develop a notion of how the resistivity values respond to vertical, lateral lithology, and facies changes within the oil field (Figure 2).

Deep resistivity modelling (water and oil legs)

A detailed, careful mapping process for average deep resistivity has been performed in all available wells (oil-leg and water-leg) by using the top reservoir map as trend map during the modelling process (Figure 5), then a simple grid was created for the top and bottom reservoir.

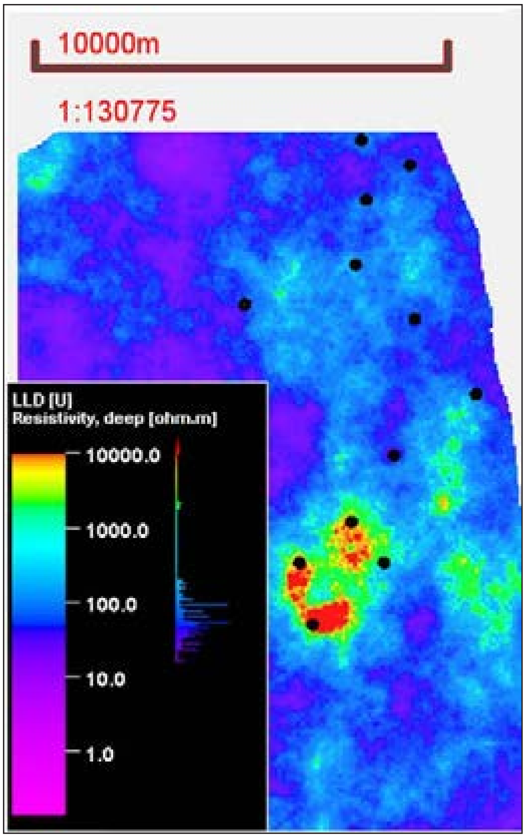

Figure 5: Deep resistivity map for the oil leg within the field for height above free water level estimation.

After that, the average resistivity were populated using Random Gaussian distribution (Figure 5). Similarly, the analysis were repeated in the water-leg.

Height above free water level

Once all the resistivity maps were modelled in the reservoir, it is very crucial to understand the reservoir pressure and fluid densities and distribution. In doing so, the density of oil, water and fluid contacts were obtained from repeated formation test (RFT) data provided by Operator Company, and then height above free water level has been determined by applying the following equations to both logs and core data.

$H = SSD - OWC\ (ssd)$ ……………………..…........... (1)

Where, (H) is height above oil-water contact, (SSD) subsea depth and (OWC) oil-water contact (Figure 6).

Reservoir capillary pressure determination:

$P_c = (H/144) * (\rho_w - \rho_o)$ ……………...……...…......... (2)

For converting laboratory reservoir capillary pressure to reservoir conditions

$P_{c,r} = P_c\,(\Delta\rho) * 26/76 = P_c\,(\Delta\rho) * 0.361$ ……........ .....(3)

Then calibrate the estimated capillary pressure to a height above the free water level in the reservoir conditions, by:

$$H=P_{c,r}/P_c(\Delta\rho)=P_{c,r}/(0.44\text{-}0.33)\ldots\ldots\ldots\ldots(4)$$

Where, ($P_{c,r}$) capillary at reservoir conditions, ($\Delta\rho$) difference between water and oil densities, 0.44 psi/ft. water gradient at reservoir initial condition, and 0.33 psi/ft. oil gradient at reservoir initial condition.

RESULTS AND DISCUSSION

The resistivity map exhibited a typical resistivity value for brine filled sandstone reservoirs; the highest deep resistivity value is 35 ohm-m, scattered along the eastern boundary of the oil field, while the lowest resistivity readings can be seen in the south-west and the middle part of the oil field (Figure 5).

The oil-leg highest resistivity values recorded is more than 10,000 ohm-m and scattered near the south-west boundary of the oil field; also some lower connected and disconnected low resistivity zones (10-50 ohm-m) can be outlined, especially, in both middle and southern parts (Figure 6).

Figure 7 shows S-NW cross-section view at the location of high resistivity wells (W07 and W08), where the high resistivity anomalies above 10,000 om-m are scattered within the top upper reservoir unit known as "clean Mamuniyat" reservoir and confirming the upper oil-water contact reservoir at this closure. However away from the closure centre resistivity values decays until it gets back to a normal one.

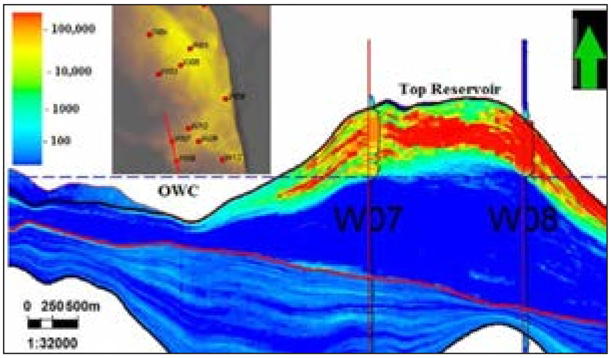

Figure 6: A cross-section of resistivity distribution in the location of high resistivity wells after the correction and modelling.

In the other wells such as W04 and W03, the resistivity of the same reservoir unit is below 100 om-m and even lower in the remaining wells (Figure7). This might be a result to thinner "clean Mamuniyat" reservoir in these wells than in the wells with high resistivity readings.

Similarly to the above deep resistivity map, the estimated height above water level and capillary pressure have their highest values in the exact areas where extreme deep resistivity readings were recorded, around 120 ft. Moreover, 4000 psi respectively (Figure 8).

Due to substantial capillary pressure in the areas with a higher hydrocarbon columns, oil might have been able to enter smaller pores and replace water. Through benefitting from high connate pressure and buoyancy forces support, occupying all the minor pores and forced the water into larger scattered pores leading to a gradual local alteration of reservoir wettability.

Hence, the brine fluids will no longer be connected to each other inside the pore system and they will lose their contribution to resistivity readings. When the resistivity readings are conducted in such clean and highly permeable oil-wet sandstone reservoirs, it is very likely that the resistivity current tends to follow the passes where the conductive mineral or fluid exist (Anderson, 1986a, 1986b; Donaldson & Siddiqui, 1989; Toumelin & Torres-Verdin, 2005; Feng *et al.*, 2016). The absence of the conductive connected brine fluid and the existence of mostly resistant clean quartz aranite (with a resistivity of more than 500 k ohm-m) (Anderson, 1986b), resistivity current will have to flow either through oil since it is the connected wetting phase or through the rock composition itself or both. Although the latter two observation yet to be accurately proved by conducting more analysis about the things that might cause an increase of origin rock resistivity that isn't applied to current cases, such as lack of pore fluid fill, lower salinity, compaction and lithification (Anderson, 1986b; Donaldson & Siddiqui, 1989).

The distribution of high resistivity zones is largely controlled by the clean reservoir facies association (FA3 and FA5) that is composed of clean medium blocky sandstone and clean coarse sandstone (Figure 9).

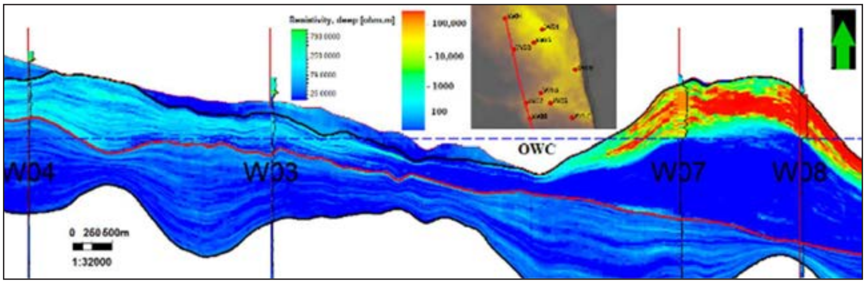

Figure 7: S-W cross-section of resistivity trend in the location of high and standard resistivity wells.

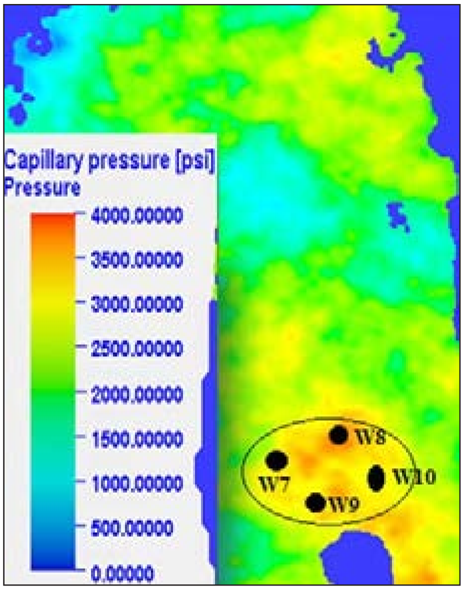

Figure 8: The estimated capillary pressure map for the reservoir within the Sahara field.

CONCLUSION

The type of reservoir facies, height above free water level and the pressure of hydrocarbon occupying the connected pore system significantly control the distribution of high resistivity layers for the Upper Ordovician reservoir.

Finally, it is believed that by applying this simple, quick and cheap methods in similar cases will help enrich exploration and production activities choices. By considering different scenarios for calculating sensitive reservoir properties such as fluid saturation and carefully plan the field development injection wells for the wet oil system rather than just injecting water into the reservoir which is often effective in water-wet reservoirs system. Thus, an early highly possible water breakthrough can be avoided.

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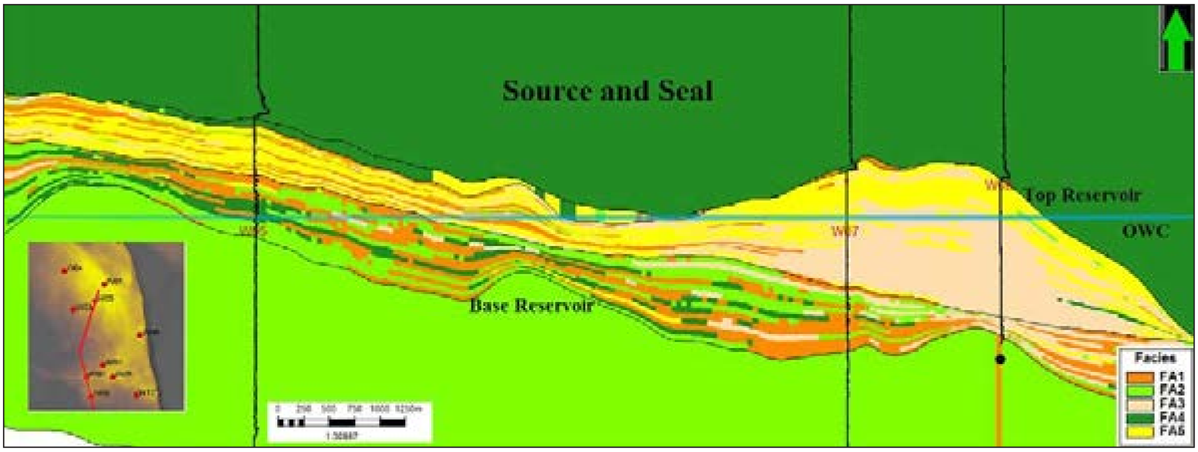

Figure 9: S-W cross-section of resistivity trend in the location of high and standard resistivity wells.

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Key principles and approaches in geohazard communication for enhancing disaster resilience

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Abstract: Communication is an essential aspect of preparing for, avoiding or responding to the occurrence of natural geohazards. As such, it forms an integral part of any strategy to enhance resilience to geohazard events. Conversely, inadequate or lack of communication is a common factor in failing to minimise the risks involved. Communication about geohazards occurs at several different levels: between geoscientists and other professionals such as the engineers and planners; between professionals and other groups such as emergency services and insurance companies; and between all of these parties and the general public who are affected by events. Geoscientists need to be involved in all of these lines of communication. This paper examines the essential role of geoscientists in helping to reduce the risks associated with a wide range of geohazards. A series of key principles that links to a generic model of geohazard communication applicable to a wide range of scenarios is presented.

Keywords: geohazards, natural hazards, geoscience communication, disaster risk reduction, disaster resilience

Abstrak: Komunikasi merupakan aspek penting dalam siapsiaga, penghindaran dan tindak balas terhadap kejadian geobahaya tabii. Ia adalah teras utama kepada pembinaan daya tahan terhadap impak geobahaya. Sebaliknya, kegagalan dalam komunikasi seringkali mengakibatkan sesuatu risiko tidak dapat dinilai dengan baik atau dikurangkan. Komunikasi risiko tentang geobahaya dapat dibahagi kepada beberapa peringkat dan kumpulan pihak berkepentingan, iaitu profesion geosaintis dengan profesion lain seperti jurutera dan juru perancang bandar; kumpulan profesion dengan kumpulan perkhidmatan kecemasan dan syarikat insurans; serta kumpulan profesional dengan orang awam. Geosaintis mempunyai peranan tersendiri dalam setiap peringkat kerjanya dan komunikasi dengan kumpulan tersebut. Kajian ini mengkaji kepentingan keterlibatan geosaintis dalam pengurangan risiko untuk pelbagai jenis geobahaya. Berdasarkan senario kerja-kerja geosaintis, beberapa prinsip dan amalan telah dikemukakan untuk membolehkan komunikasi maklumat geobahaya dapat dilaksanakan.

Kata kunci: geobahaya, bahaya tabii, komunikasi geosains, pengurangan risiko bahaya, dayatahan bencana

INTRODUCTION

Resilience is defined by as “the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions” (UNISDR, 2009). Resilience helps to reduce the vulnerability of a community to a known hazard. It can be achieved, in part, by avoiding development in hazardous locations through spatial planning, and by providing and responding to effective early warning systems. Resilience also entails planning and designing effectively for the continued functioning of critical infrastructure in the event of a disaster, in order to provide essential support to communities during the event and to ensure that full services can be restored as quickly as possible thereafter, during the recovery phase (Auckland Council, 2014).

Through a combination of climate change, increasing population and expanding development pressures, the magnitude, frequency and consequential risks associated with natural hazards are all increasing. In order to build resilience and adaptation strategies against these events, and to respond effectively when they occur, geoscientists have a pivotal role to play in conveying information to other people on the hazards and risks within particular areas, and how to deal with them. Irrespective of the nature of the hazard, reliable information is needed in several different stages, prior to, during and after an event. This has been demonstrated in developing detailed planning guidance to address the risks posed by subsidence hazard in Ripon, in the United Kingdom (Thompson *et al.*, 1996; 1998). A similar liaison between geoscientists, engineers, planners, insurers and others has been illustrated in dealing with the aftershocks of the Canterbury Earthquakes in New Zealand (Becker *et al.*, 2015). In both cases, the geoscientists assessed what was needed, through dialogue, before developing the advice or guidance that was needed.

This paper draws on a generic model of geohazard communication, which was developed from the Ripon experience (Thompson *et al.*, 2019). The focus is primarily on the initial stages, leading up to and during an event, with particular emphasis on improving resilience and preparedness. The purpose is to highlight key principles related to a generic model of geohazard communication that is capable of being applied to a wide range of scenarios. The importance of communication, particularly two-way communication and collaboration is emphasised.

LEVELS OF COMMUNICATION

Risk communication is grounded in an assumption that the public should have a generalised right to know about hazards and risks (Reynolds & Seeger, 2005). The availability of information allows the public to make informed choices regarding risk and, in this way, risk communication facilitates both decision-making and risk-sharing. While having a level of hazard awareness is an important initial step towards becoming better prepared, a high level of awareness does not necessarily mean that the public either have the correct knowledge or are able to act upon it, when needed, to reduce their risks (Amri *et al.*, 2017). Careful consideration needs to be given to the type of information communicated to different groups of people, taking account of what they need to do with that information within the overall scheme of risk reduction, and to the method of communication used.

Geohazards, however, are usually complex phenomena which are best understood by technical experts, i.e. geoscientists. Moreover, the technical information possessed by the scientists is rarely in a form that can readily be understood or acted-upon by those who need to respond to the levels of risk associated with geohazard events – whether they be politicians, decision-makers, members of the emergency services or members of the public. Relevant information needs to be explained in terms that meet the requirements of each group (McKirdy *et al.*, 1998; Marker, 2008; Liverman, 2008), so that considered decisions and actions can be taken, without causing undue fear, panic or complacency. Communication of information about geohazards and associated risks is required at three levels:

- between the geoscientists who study, develop understanding of and monitor the natural processes involved, other specialists involved in risk assessment, and the engineers and planners who design or plan for appropriate solutions;
- between any of those groups and the emergency services and insurance companies who need to respond to events and/or support recovery thereafter; and
- (not least) between all of these and the general public who need to be aware of hazards and how to react to them.

Geoscientists therefore need to be involved in all of these lines of communication, so that they can help to ensure that reliable information is provided in a readily accessible way and is properly explained. A key feature is that the information given to each group needs to be different: customised to ensure that it can be understood – and acted upon – by the 'target audience' involved and integrated into their own procedures. It should be recognised that communication about hazard and risk is not just a one-way process. It requires frequent interaction, dialogue and collaboration, so that information is properly tailored to the requirements of those who need to use it. Feedback is vitally important. Risk communication is "an interactive process of exchange of information and opinion among individuals, groups, and institutions" (National Research Council (US) Committee on Risk Perception and Communication, 1989).

KEY PRINCIPLES OF COMMUNICATING GEOHAZARD AND RISK INFORMATION

There are four key principles critical for geohazard communication. The first is for geoscientists to have a thorough understanding of the hazards involved so that they can explain these to people with limited or no specialist knowledge. Being able to explain scientific concepts clearly to non-specialists is a skill in itself and an important pre-requisite to holding meaningful discussions with others. Three additional key principles include the need for information to be customised to the needs of each different target audience; for the communication to be a two-way process in each case; and for the information to be delivered, as appropriate, to each group. The four key principles for transmitting information on hazards form a logical sequence, within which there are eight stages of geohazard communication (Figure 1).

Key principle 1: Understand the hazards and associated risks

This is traditionally the main focus for most geoscientists involved in the study of geohazards and will

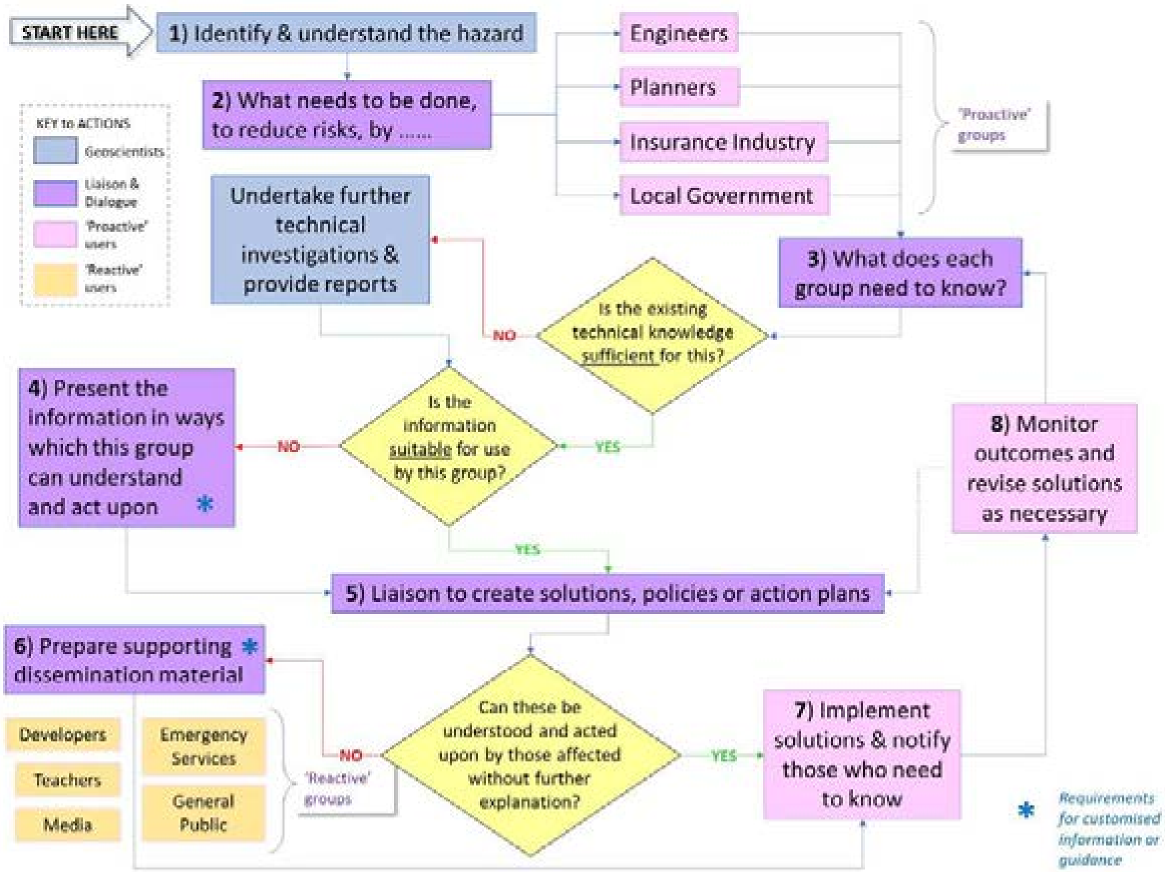

Figure 1: Generic model of geoscience communication in relation to geohazards (Source: Thompson *et al*., 2019).

generally be at a detailed, technical level. Information will routinely be exchanged between geoscientists on this level and will be published in scientific journals and conference proceedings. It is extremely important, however, for the level of understanding to go deeper than this, such that the scientist is able to explain things in 'plain language' without the use of technical 'jargon'. This is a skill in itself. It does not mean 'dumbing down' the information; it means explaining it properly. This involves: identifying all that you know about a particular subject; explaining this knowledge to a (real or imaginary) non-expert audience, such as an intelligent, enthusiastic child; using this to identify gaps in your knowledge; filling those gaps by learning more; and reassembling the information into a logical narrative, or story (Feynman, 2006).

Investigate and analyse the physical processes involved: The starting point, however, is for geoscientists to investigate and analyse the geohazard itself in as much detail as possible, using all available data. There is substantial scope - and necessity - for hazards to be investigated from a 'pure science' perspective, so that confidence can be built in our understanding of the processes and triggering mechanisms involved, and of the interaction between these processes and geological materials (rocks, sediments and soils). There is also a need to document and analyse historical hazard events so that empirical observations can be used to develop, refine and calibrate numerical models (e.g. of slope instability or fluvial flooding) or at least to develop conceptual models of more complex processes such as karstic dissolution and subsidence. The more data available (provided that it is accurate and verified), the more reliable will be any hazard assessments or forecasts that are made.

Additionally, there is considerable scope to undertake more explicitly 'applied' research, so that models and analytical programs are developed and tested for use in relation to real-world development scenarios. These may include highway engineering schemes, high-rise development on steep slopes, or urbanisation of river floodplains. Such schemes frequently present major challenges to geoscientists and engineers; testing the limits in terms of what can be achieved through engineering design in a battle against natural processes. In many countries, including Malaysia, immense pressures for economic development are increasingly in conflict with geohazards associated with land instability and flooding. The battle is relentless and the stakes – in terms of the risk of increasing societal costs associated with natural hazards – are ever increasing.

It is increasingly important, however, for geoscientists to learn – and step back from – the limitations of this approach. It will not always be possible to find a reliable or cost-effective engineering solution. Applied research should include learning more 'abstract' lessons about which areas are likely to be affected by certain types of hazard, so that future development can – as far as possible – be directed elsewhere. In cases where there are genuinely no alternatives, the same information can be used to quantify the levels of risk involved, the advisability (or otherwise) of the proposed development and the necessity for mitigation, monitoring and emergency response. Professional advice on such things needs to be taken on board by those responsible for sanctioning development within hazard-prone areas and needs to be reflected in the budgets made available – both for capital works and recurrent contingencies.

It is therefore of fundamental importance that geoscientists should understand the nature of each geohazard in as much detail as possible so that development decisions – whether by engineers, planners or other decision-makers - can be properly informed. Geoscientists also need to be sure about the limitations of their knowledge, so that models and predictions are kept within sensible bounds. Ideally, geoscientists need to be closely involved in the development, calibration and 'reality checking' of numerical models (rather than leaving this task wholly to the modelling experts) so that the information passed on to engineers, planners and others is reliable.

Explain the hazards, and their development implications, in 'plain language': The key to successful communication is to make sure that the appropriate information is given out and that everyone understands, and can act upon, what is being said. In order for geoscientists to be able to get their message across to those who need to act upon the information, it is essential that appropriate 'plain language' is used, avoiding the use of technical 'jargon' (Marker, 2008, Liverman, 2008). Geoscientists need to imagine that they are explaining the situation to someone with no prior knowledge or specialist expertise – for example, to an intelligent student at secondary school or one that is entering higher education. Similar guidance is often given to an expert witness when preparing and presenting proofs of evidence at a public inquiry, or to a jury in a trial.

Even if plain language is used, it is often difficult to avoid using at least some essential technical terms which the recipient will need to understand in order to follow the expert's reasoning. For example, terms such as 'landslide', 'subsidence', 'settlement', 'fluvial', 'karstic', 'regolith', 'weathering' and even 'geohazard' are generally understood by geoscientists but not by many others. All such terms should be explained when they are first mentioned, whether in a public presentation or in the text of a report. They should also be defined in an accompanying glossary or online resource. When talking about the risks associated with particular hazards, it becomes especially important to use clear and consistent definitions of the terms being used. Terms such as 'hazard' and 'risk' are often used interchangeably when, in fact, they have different meanings (Auckland Council, 2014).

Explain the levels of confidence involved: Although modelling is vital for all phases of natural hazard risk assessment and disaster management, communicating the uncertainty that is inherent in these models, and between different models which give a range of different outcomes or views, is a challenging task (Doyle *et al.*, 2019). Equally, they point out that not communicating these uncertainties, in an attempt to avoid overwhelming or confusing the receiver, can also be problematic. This is particularly so in the case of multi-model or cascading models where uncertainties can be compounded to give very large margins of error. Scientists must first understand decision-maker needs, and then concentrate efforts on evaluating and communicating the decision-relevant uncertainties, in a way that can be understood (Doyle *et al.*, 2019). Once again, collaboration and two-way communication is seen to be the key.

There is always a concern that conveying a low degree of confidence in modelling predictions will fail to elicit any urgent response from decision-makers. However, by ensuring that the issues have been properly discussed, then at least it will be possible for informed decisions to be made. Failing to disclose the uncertainties could risk urgent warnings being issued without justification, leading to widespread mistrust in the modelling and warning systems, with potentially catastrophic consequences in future events. With regard to public warnings that are issued ahead of a forecast event, in order to be effective, it has been argued that the warning message needs to convey a high level of certainty about the event and what people should do (Mileti, 1995). Even if there is only limited confidence in the forecast, or an ambiguous situation, the message about it should be stated with certainty. That is not to say that the confidence of the prediction should be overstated; only that the message should provide confidence that the warning is real and should be heeded, even though it may be precautionary.

Key principle 2: Identify 'target audiences'

Geoscientists will sometimes know, intuitively, what needs to be done – e.g. whether the hazard itself can be reduced in some way; whether it can be avoided, through well-informed spatial planning; or whether it is likely to require emergency evacuations in response to warnings.

However, they will need to liaise with other professionals (those with the responsibility for carrying out these actions) in order to discuss the feasibility, or otherwise, of different approaches, and so that they can understand exactly what those groups of people need to do (Thompson *et al.*, 2019). In this way, geoscientists can tailor their inputs and advice accordingly. This serves to re-emphasise the importance of two-way communication. By engaging in early dialogue with the various different groups, an exchange of understanding, as well as information, can be developed, which can then lead to effective collaboration.

The need to differentiate between different target audiences in terms of the types of information required and the methods of communication to be used is nothing new (e.g. McKirdy *et al.*, 1998, Reynolds & Seeger, 2005; Marker, 2008; Becker *et al.*, 2015; Midtbust *et al.*, 2018; and Doyle *et al.*, 2019). In the geohazard context, it is useful to consider the potential range of different audiences in two main categories: those who need to be proactive in risk reduction such as engineers, planners and insurers; and those who would need to be reactive to any warnings that are given including developers, emergency services, the general public, and the media (Table 1). The two categories are somewhat flexible, since particular groups may behave either proactively or reactively in different circumstances.

Key principle 3: Engage in dialogue

Having established which groups of people they need to liaise with, there is a need for geoscientists to understand

Table 1: Outline of information likely to be needed by various user groups in dealing with geohazards.

Types of Information / Guidance	"Proactive" User Groups				"Reactive" user groups			
	Engineers	Planners	Local Government	Insurers	Emergency Services	Developers	General Public	Media
Detailed technical information (including historical + monitoring data) on the nature, timing, causes, behaviour and spatial distribution of specific hazards *	✓			✓				
Simplified but clear and comprehensive advice on the nature, significance, magnitude, probability and spatial extent of the hazards **		✓	✓	✓				
Simplified summaries of key information on hazards, solutions and actions required**					✓	✓	✓	✓
Detailed technical input / comments on appropriate engineering solutions**	✓							
Clear, reasoned advice on appropriate planning approaches, including both forward planning policies and development control procedures**		✓	✓			✓		
Clear understanding of the need for rapid communication and the types of action required by emergency workers in response to warnings**			✓		✓			
Customised advice to provide an understanding of their full range of responsibilities**			✓		✓	✓		✓
Straightforward explanations on what to do in response to warnings**			✓				✓	
General guidance on responsible communication of hazard and risk information**	✓	✓	✓	✓	✓	✓	✓	✓

NOTES: * information or guidance produced by geoscientists. ** Information or guidance produced by geoscientists in collaboration with the relevant 'target audience' the type, and level, of information required, and what each group needs to do with that information in order to play its part in reducing the impact of hazardous events. This aspect includes additional steps for making sure that sufficient information is available, obtaining additional information, where necessary, and checking that the information is suitable for use by the intended audience (Figure 1). The objective, in all cases, is to ensure that each group can understand and act appropriately upon the information received. Once again, this requires close collaboration and two-way communication. Each of the groups listed in will have different requirements for information, based on the actions which they themselves need to take and the levels of interest and existing awareness or understanding which they are likely to have (Table 1). Precise details will vary from one situation to another and the following suggestions provide only a very general guide.

Proactive Groups: Civil engineers, including those responsible for the safe design of buildings, foundations, highways, railways, reservoirs, canals, flood defences, pipelines, coastal/sea defences etc., need detailed technical advice on the nature, scale and geographical location of the hazard, together with input from geoscientists to discussions on the range of engineering solutions and responses which may or may not be appropriate. Such advice may be needed both in the context of reducing or mitigating the hazards themselves, and/or in the context of remediating damaged areas following a hazard event. As previously noted, in some cases, the nature and scale of the hazard may be such that engineering responses or solutions might not be appropriate at all or may impose unaffordable costs. Geoscientists also have an important role to play in providing advice on these situations, based on their own specialist knowledge. Planners, regulators and inspectors (including those responsible for land zoning, policy development, building control, or the determination of planning permissions or licences, and the implementation and enforcement of conditions) need simplified explanations of the hazards and their spatial extent, together with clear explanations of what needs to be done by them in order to guide new development to the most appropriate (safe, sustainable and environmentally suitable) locations and to provide the necessary control. Local government officers generally need to understand their full range of responsibilities – particularly for communicating key messages about hazards, solutions and opportunities – but also for the coordination of planning, public warnings and emergency responses. Insurers need to understand the scale, probability and spatial patterns of risk, including access to the underlying technical datasets (e.g. on the magnitude, frequency, location and consequences of previous events), in order to be able to assess their own overall risks and thereby provide appropriate insurance cover at affordable premiums. Also, sound information gives a basis for re-insurers against large scale disasters to plan ahead.

Reactive Groups: Emergency services, including fire fighters, search and rescue teams, police, ambulance services, the army, civil defence and emergency rescue volunteers, need an awareness of the types of hazard involved and a clear understanding of the types of action required in response to specific warnings, in order to keep people safe. They need to be clear about relatively safe facilities and about planned evacuation and intervention routes. They also need to be aware of how best to communicate information to their workforces, the public and the media. Developers, including their architects and consultants, need to understand the planning and other regulatory requirements relating to hazard mitigation and the need for compliance because of environmental limitations on safe development, even if that reduces profits. They also need to understand their legal liabilities and moral responsibilities for safe development within hazard-prone areas. In the UK, developers are often also required, through planning conditions and/or legal agreements, to provide compensatory measures (such as natural wetland areas to alleviate flooding), in relation to development that would otherwise have an adverse effect. The general public, including community groups, lone individuals, teachers and children, need to have a general awareness of the hazards and an understanding of the importance of taking action to reduce their vulnerability. In particular, they need straightforward, clear and authoritative explanations on what to do in response to warnings.

Local communities can also play an important role in understanding local hazards themselves and two-way communication with these groups can be essential in carrying out vulnerability assessments (Catto & Parewick, 2008). Unlike the various other categories, communication with the public will often require (or at least, will benefit greatly from) an understanding of social psychology and will therefore usually require geoscientists to work in close liaison on this with appropriate experts within national, regional or local government or involved institutes. People who receive warnings first typically go through a social psychological process to form personal definitions about the risk they face and ideas about what to do before they take a protective action (Mileti, 1995). Public warning systems that take this process into account can be very effective in helping at-risk publics find safety before disasters strike. It may be difficult for people to understand a hazard warning when they do not understand much about the hazard itself – hence the need for carefully explained general information as well as (and in advance of) specific emergency warnings. Such information may also be beneficial in overcoming 'fatalistic' attitudes among some groups, including those which may be linked to long-held beliefs or ideologies, so that they are more likely to take heed of warnings when they are issued. It may also be beneficial for open explanations to be given immediately after disaster events, so that people can make sense of the situation and have confidence in future warnings. Effective public warnings must also provide for public interaction and foster the search for further information in addition to received warnings.

The media including television, radio and internet broadcasts, social media platforms and newspapers, are a special category in publicising information relating to geohazards. Media communications can be beneficial both in advance of any specific events, as part of the general public education and awareness, and as an integral part of any public warnings and rescue or recovery advice that is given immediately before, during and after a particular hazard event. But the media can also have very negative effects if not properly controlled. Hazard and risk information and warnings that are issued to the media by geoscientists or others therefore need to include clear but measured advice on the nature of specific hazards; the actions which are being or will be taken by planners, emergency services and other groups in response; and the importance of responsible communication.

Information Quality: As well as considering the various types of information required, consideration also needs to be given to the relative importance of different characteristics or qualities of information, in each case. Not all information needs to possess the high standards of technical accuracy and precision as that which is exchanged between geoscientists, or between those scientists and engineers. For other audiences, the emphasis should be on providing an appropriate level of simplification – without compromising essential accuracy – and on being as concise as possible. In all cases, there will be a need for clarity, and the avoidance (or clarification) of doubt.

Key principle 4: Deliver the required information

The generic model envisages that delivering the information is expanded into a number of separate stages: modifying the information (where necessary) to suit the user's requirements; liaison with the users to produce appropriate solutions, policies or action plans, and any supporting dissemination material that is likely to be required; then implementing those solutions and finally monitoring the outcomes to ensure that they remain 'fit for purpose' (Figure 1). The most effective method of communication for delivering information to the various user-groups will clearly vary from one group to another and with the nature of the specific task (with an obvious distinction, for example, between general information that is used to improve background awareness and preparedness, and that used for urgent warnings). The selection of appropriate media depends on suitability for the intended audience, penetration to the intended user group, cost and the possible need for future revisions of materials.

Detailed technical reports supported by database information, numerical modelling and other forms of computational analysis will be essential for communication between technical specialists within and between the geoscience and engineering sectors. Such reports, however, would be wholly inappropriate for passing information on to planners, politicians and other decision-makers. Instead, there is a need for such information to comprise simplified but accurate 'plain language' documents, maps (whether in printed or electronic form) and other graphics, each of which are tailored to the requirements of individual user-groups.

For the general public, including teachers, school children and students, similar information and guidance can best be provided by simplified but accurate educational programmes, broadcast from responsible sources via television, radio and/or the internet. For more detailed or site-specific information, which encourages the public to become more engaged with the issues, it may be possible to make use of mobile apps such as those used in connection with Singapore's citizen science engagement around flooding (https://www.mewr.gov.sg/topic/flash-floods) or flood risk mapping in the UK (http://www.knowyourfloodrisk.co.uk/). Alternatively, a good example of an online booklet written in plain language is that provided by Hong Kong's Civil Engineering and Development Department regarding landslide hazard and risk (https://www.cedd.gov.hk/eng/publications/geo/natural-terrain-landslide-hazards-in-hong-kong/index.html).

In the case of more urgent information, such as warnings issued in advance of forecast events and during actual events, other lines of communication will become increasingly important. Confidential daily bulletins may need to be issued routinely by those responsible for monitoring potential geohazards, in order to maintain an appropriate state of readiness amongst the various 'proactive' user groups (e.g. between local government and emergency services). Public warnings, when required, will also need to be issued by a respected, central, coordinating authority. People generally prefer to trust experts rather than media reports (Ahmad *et al*., 2014). While this is understandable, the importance of the formal media (newspapers, television, radio and internet broadcasting) in being able to disseminate information cannot be underestimated. It is important, therefore, that these outlets are provided with appropriate – suitably balanced and accurate – messages which are clearly linked to the advice from geoscientists and other trusted experts.

In Malaysia, the short message system (SMS / text messaging) is used to issue alerts to relevant officers in-charge of government agencies (Noorhashirin *et al*., 2016). It has been suggested that such alerts be extended to the general public community because of its speed, effectiveness, and functional resilience to disaster. To be effective however, such messages must always be carefully worded to avoid confusion and panic, and they must be credible, reliable and capable of being understood by the target audience, especially in rural areas (Sahu, 2006). For maximum effectiveness, SMS messages need to be backed-up by confirmatory and more detailed information issued via other means, such as television, radio, websites and social media (Niles *et al.*, 2019). While social media provide a corroborative source of information during hazard events, it can just as easily be the cause of disseminating misinformation (or 'fake news'), whether through a lack of understanding or mischievousness. This highlights the absolute necessity of being able to issue clear, accurate and authoritative information, as rapidly as possible, through reliable broadcast or electronic media or directly from respected (often government) sources. Frequently repeated warning messages can help to reduce the effect of misinformation and misperceptions (Mileti, 1995). They can focus people's attention on official messages, reduce rumours, and increase public confidence in the validity of the warnings.

KEY PRINCIPLES IN ACTION

The generic model was based on the case of Ripon, in England, where a comprehensive study of subsidence hazard was funded largely by the UK Government and partly by the local planning authority (Figure 1). There was a need for the local planning authority to guide new development towards relatively safe areas, unaffected by subsidence (Thompson *et al.*, 1996; 1998). The solution was found through dialogue and close liaison between planners and geoscientists with expertise in engineering geology, geomorphology, hydrogeology and hydrochemistry (Thompson *et al*., 2019). The solution was implemented primarily through policies within the Development Plan for the area and has subsequently been monitored and improved, where necessary (primarily to ensure continued compliance with changes in professional standards for geotechnical expertise). The policies were accompanied by information and guidance issued to all prospective developers and by summary information issued through local newspapers to the general public. This was primarily to reassure the public that, although the risk of subsidence needed to be taken seriously, the likelihood of this occurring at any given location was generally quite low.

Additional case studies, based on this generic model, were developed for the project on "Disaster Resilient Cities: Forecasting Local Level Climate Extremes and Physical Hazards for Kuala Lumpur", funded by the Newton-Ungku Omar Fund. These encompassed landslides in Columbia; flood risk mapping in the Asia-Pacific region; and rockfall hazard and risk assessment in Malaysia and elsewhere (http://ancst.org/nuof/publications-reports/). All these case studies involve the communication of geoscience information. They were compatible with the generalised model described above and, together, illustrate how various approaches can be developed within the overall framework. Several training sessions were held under the aegis of the Geological Society of Malaysia, a consortium member of the Newton-Ungku Omar Fund project. The training involved participants from the region, who had developed case studies on hazards in their respective countries, a few of which were published (Manh, 2018; Naing *et al.*, 2018; Seng, 2018; Khan & Shah, 2019). During the hand-on-training, the generic model was found to be applicable to their respective work. The geohazard communication model is now being disseminated to be used in training modules for geology practitioners.

CONCLUSION

Effective communication of geoscience information is important for developing suitable responses to a wide range of geohazards. The role of the geoscientist is essential – not just in recognising and investigating the hazards – but also in liaising and collaborating with a variety of other practitioners, so that accurate and reliable information is communicated to those who need to use it, in a form that they will understand. Four key principles of geohazard communication have been identified to provide a framework to guide geoscience communication which can be adapted, as necessary, and applied to many different circumstances and geographical areas. The principles are linked to eight stages of a generic model for geohazard communication that has been tested in the field and found applicable to the region.

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Engineering geology in the mining and quarrying industry

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Abstract: Engineering geology is combining the application of engineering and geological principles to the behaviour of the ground and groundwater and the use of these principles in various industries including mining and quarrying industry. The stability of the mine pit wall or quarry face are paramount important in day-to-day operation to ensure safety to the people and surrounding environments. This paper attempts to highlight the function of engineering geology in mining and quarrying industry in Malaysia that being dominated by foreign consulting company. This paper also presents some local case studies on the engineering geological assessment of quarry faces and mine pit walls which included assessment, analysis and recommendations on rock slopes for two limestone quarries, 1 gold mine and 1 tin mine respectively. Site No. 1 (Quarry) has rock fall issue that may endanger nearby villages following significant rockslide occurred nearby area. Engineering geological assessment was carried out to assess the stability conditions as well as to demarcate the safety zone based on guideline provided by Jabatan Mineral dan Geosains Malaysia (JMG). Engineering geological assessment of Site No. 2 (Quarry) is more focussed on rock slope and cave stability as well as to demarcate zone of rockfall hazard in view of continuous quarrying activity that includes frequent blasting. The safety limit or factor for blasting requirement was identified and recommended. Engineering geological assessment of Site No. 3 (Gold Mine) more on desk study of available data as well as few site visits while the engineering geological assessment of Site No. 4 (Tin Mine) focus on the geological field survey and the use of surveying technique to gather field data. Every site has their own unique problems and way to assess it. Most of the studies carried out involves discontinuity and topographic mapping using scanline method, photogrammetry, terrestrial laser scanning, drone as well as field and laboratory testing of rock strength and other geomechanics properties. Failure modes such as planar, wedge, toppling or circular were identified after kinematic analysis. Slope Mass Rating (SMR) analysis were conducted to counter check with other results. Rock fall run out analysis were also carried out to determine the maximum rock fall distance down the slopes of the hill due to concern of elements at risk located near the foothill. Numerical modelling simulation was also performed in one of the case studies using both continuum and discontinuum model to determine the rock mass behaviour upon blasting. Exploration drilling exercise should also include gathering geomechanics parameters to optimise drilling operation as well as the cost. Multidisciplinary approach is recommended to identify, analyse and solve the engineering geological issues at mines and quarries sites.

Processing of Malaysian bauxite

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Abstract: A study on local bauxite was conducted to produce highly purified fine alumina (Al_2O_3) powder. The characterizations of the sample were determined by X-ray fluorescene (XRF), X-ray diffraction (XRD), microscopic and scanning electron microscope (SEM). The XRF result showed that the raw material being classified have the major constituent of Al_2O_3 (58.7%) followed by SiO_2 (7.2%) and Fe_2O_3 (3.71%). Based on the XRD result, the major mineral was detected as gibbsite. Grindability tests were performed on crushed sample to determine the suitable feed size for leaching test by means of Bayer process. As a treatment process magnetic separator was employed to remove iron content (Fe_2O_3) from the mineral sample. The ground sample was then subjected to Bayer process by dissolving the aluminium component of bauxite ore in sodium hydroxide (caustic soda to produce sodium aluminate solution (pregnant solution). The dissolved alumina was precipitated from the sodium aluminate solution in the form of $Al_2O_3.3H_2O$ (alumina trihydrate). During the precipitation process, pH 11.8 was found to be optimal for producing alumina trihydrate with 63.88% Al_2O_3 precipitated. It is suggested due to species region gave highly supersaturated of alumina, and apparently the adhesive interaction force between particle and nuclei can enhance agglomeration process of alumina.

The way forward for Malaysia's mineral resource development

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Abstract: Malaysia's mineral resource industry has faced significant challenges since the collapse of the tin market in the late 1980s. Initially, when tin was its most important single mineral commodity, and when its price became unremunerative coupled with depletion of alluvial reserves, the industry was set for a decline. Subsequently, however, as the industry diversified its portfolio to other metallic and non-metallic mineral commodities, the mining industry somewhat picked up.

It was not smooth all the way as volatile mineral commodity prices created bumps which at times brought misery and other times brought euphoria. Attempts to promote mineral investments were generally not very successful. The fiscal regime in most states were daunting and the regulatory framework did not facilitate easy access to exploration or mining areas of mineral potential. On top of that, miners had to be content with non-governmental organisations (NGOs) which continuously picked on the negative aspects of mining.

Mineral resource development is high risk and capital intensive. The Government cannot undertake mineral resource development without private sector participation. Hence, the government needs to attract investors with the necessary appetite and venture capital who are willing to take the high risk. The way forward is to make it both attractive and conducive to invest in mineral resource development in Malaysia. To do that, the fiscal regime needs to be competitive enough to allow investors to make a reasonable return while at the same time bring reasonable revenue and benefits to the nation, state and community. Incentives need to be given. The legal framework should be clear, investor friendly, transparent and fairly enforced. Environmental concerns should be well and strictly managed to ensure mining is done in a responsible and sustainable manner so that there is a social licence to operate especially from the local community.

Borneo Oil & Gas Corp. Sdn. Bhd. Bukit Ibam Gold Project, Pahang: Review of the recent mineral exploration and discoveries

CHEZE Yves

Abstract: The BORNEO OIL & GAS CORP. SDN BHD ("BOG") Bukit (Bt) Ibam project is located in the southeastern state of Pahang of peninsular Malaysia, about 40 km to the North of the city of Muadzam Shah.

It is situated along the East peninsular Malaysia Permo-Triassic complex that hosts several iron, base metals (Chini, Mangapur etc) and gold primary deposits including Bukit Ibam, Mersing, as well as numerous artisanal alluvial gold mining operations.

The Bukit Ibam Gold project has been the object of multiple phases of shallow mining by different operators, mainly for the upper part of the oxidised zone. The gold mineralization is mainly in the form of free gold believed to be hosted by a set of highly fractured and silicified NS intrusive sub-volcanic felsitic sills. The system which has been recognized over about 2 km along the NS strike is affected by oblique regional fracturation separating and slightly shifting the formations, resulting in a typical tectonic of block faulting well marked in the topography by creeks and by hills aligned along the NS main trend. The style of mineralization visible at the BOG Bukit Ibam gold project is similar in many aspects to some other mesothermal deposits of peninsular Malaysia including Raub, Tersang etc where the gold is mainly controlled by felsitic sills and quartz stockwerks generated by a Riddel type fracturation. Over the past few years "BOG" has embarked in a detailed assessment of the gold resources, including by trenching, core, RC and blasthole drilling of one of the hills where JORC compliant resources were recently estimated.

Application of minerals in polymers and plastics industry

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Abstract: The development and advancement of human civilization have been closely tied to the ability of manipulating natural minerals to fill our needs. Ironically, period of human history has been designated to prominent minerals development of each period such as Stone Age, Bronze Age and Iron Age. In modern day, advances of material and chemical research gave birth to synthetic plastic. It is a whole new class of materials derived from polymerization process of hydrocarbon. It can be divided into two classes, thermoplastics and thermosetting plastics, depending on how they are chemically bonded. The use of plastics in engineering applications offer many advantages which are unattainable from any other materials. In fact, since the conclusion of World War II, the field of materials has been virtually revolutionized by the advent of synthetic polymers. Since then, plastics bring many societal benefits and offer promising application in many fields ranging from packaging to medical and aerospace industries. However, the chemical, mechanical and physical properties of synthetic polymers in its pure form are intrinsic in nature, that is highly govern by its molecular structure. Hence the properties become permanent once they become fully polymerized, making it very difficult to change through normal chemical reaction methods. However, this can be made possible by introducing foreign substances called ‘additives’ to enhance or modify many polymer properties, and thus render a more serviceable polymer. Polymer additives can commonly be classified into filler materials, plasticizers, stabilizers, colorants and flame retardants. Most often, these additives are actually minerals of various sources such as silica, talc, calcium carbonate etc. With the global polymer market anticipated to experience steady growth at a compound annual growth (CAGR) of 3.2% from 2020 to 2027, it will definitely favour the mineral industry as well, due to increasing demands for polymer additives. This paper will present the unforeseen contributions of local minerals in the polymer and plastic markets.

Developing selected mineral products for speciallized applications in the industries

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Abstract: Malaysia’s economy, like many countries around the world, have been greatly affected by the pandemic since the beginning of 2020. In the year prior to this, the global markets, including Malaysia’s, have already begun slowing down due to many uncertainties such as the tariff war, trade sanctions, drop in oil prices, regional conflicts and other events. In order to revive its economy, Malaysia must intensify efforts and provide greater incentives to investors and miners to explore, mine, process and extract it’s Metallic mineral resources on-shore, off-shore as well as in hard rock deposits, considering the relatively high and sustained prices of these metals. Treatment of acid mine drainage (AMD) should also be enhanced.

Gold, Rare Earth Minerals, Tin, Tantalum, Iron, Manganese, Aluminium (Bauxite) ores are required not only for basic manufacturing and infrastructure development, but also for future high-end 5G technologies, electronics, EV and space industries. Upgrading of heavy mineral concentrates (tin, ilmenite, zircon, monazite, xenotime, rutile etc) and their uses are also expected to continue unabated.

There must be continued efforts to identify and produce quality silica sand, rock and stone aggregates for construction purposes, especially for houses, condominiums, commercial buildings, factories, bridges, ports, power and cement plants. Basalt, feldspar, kaolinite, talc, wollastonite will continue to play an important role for speciallized industries in Malaysia. Coal still provides the major energy source although renewable energy alternatives are being developed to drive the consumer and industrialisation requirements of Malaysia.

Use of value-added, high quality, micronized mineral products are expected to recover to a reasonable rate in the manufacturing industries of Malaysia. These include the glass, ceramics, paint & coatings, rubber gloves, plastics, oil & gas, automotive, environmental, agricultural and electronic industries. Smaller more speciallizd applications include rockwool for insulation, filler in plastics and rubber, brake pad lining, etc. These will definitely create jobs for the youth and future generations of Malaysia, as well as spin-offs for the finance, logistics and transport industries.

Geology and mineralisation of low-sulphidation epithermal gold deposit of Mantri Hill, Tawau, Sabah

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Abstract: Mantri Hill gold project is located within the forest reserves of Mount Wullersdorf and Ulu Kalumpang on the North-western of Tawau in Southeastern Sabah, Malaysia. The exploration work of the area began in year 1986 by Zamia Sdn. Bhd. until early 1991. Detailed exploration was then continued by Southsea Gold Sdn. Bhd. from January 2013 to September 2015, where an economic mineral resource was delineated for the current pit mining operations. Limited geological studies have been undertaken of the deposit ever since its discovery by Zamia Sdn. Bhd.

The project area consists mostly of Middle Miocene to Quaternary of Semporna Volcanic (andesite-dacite) with intercalated block and ash deposit, laharic breccias, lapilli tuffs, and sedimentary clastic rocks. The structural setting is interpreted to be east-northeast-striking within the Mantri-Wullersdorf ridge bounded by two sub-parallel strike-dip fault (Zamia, 1991). Gold mineralisation in this area is related to Low Sulphidation Adularia-Sericite Epithermal vein hosted deposit (Zamia, 1991), with resource estimates of 207,000 oz Au (Optiro, 2015). Mineralisation occurs as a series of Northeast to East-Northeast striking quartz-sulphide hydrothermal breccia veins that pinch, swell, and coalesce in a sigmodial pattern typical of tension gash fractures. Principal veins are characteristically enveloped by prophylitic, intermediate argilic, silicification, late-stage kaolinitic, and ferroan carbonate alteration. The ore mineralogy is generally characterised by pyrite, sphalerite, galena, chalcopyrite, electrum-native gold, and gold-silver tellurides. Average grade of productive ores are 2.39 g/T gold (Au), 7.57 g/T silver (Ag), and 0.25% copper (Cu).

Passive treatment of synthetic AMD via Vertical Flow Bed System

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Abstract: This study was conducted to investigate the effectiveness of treatment media for iron removal and pH increment in passive treatment system. In this work, Vertical flow bed system (VFBD) was adopted using synthetic AMD and peat soil was used as a sorption media while lime stone act as neutralizing media. The effect of bed depth, metal concentration and retention time were designed using full factorial design, (2^3 +4). The treatment medium were characterised using XRF and CHNS. The XRF result shows the CaO content for limestone is 98.55% and CHNS results of organic content for peat soil was 10.693%. The iron concentration in synthetic AMD was reduced above 90% at all conditions and pH was increased from 3 to 7. The statistical analysis based on Analysis of Variance (ANOVA) shows the most significant variables on iron removal and pH increment was bed depth. It is due to the effectiveness of the organic layer to precipitate the iron by oxidation of sulphide to sulphate and the dissolution of limestone gravel in increasing alkalinity. Thus, this findings are encouraging and should be validated by using natural acid mine drainage on a larger scale.

Keywords: Passive treatment, acid mine drainage, vertical flow bed system, iron removal

Characteristics and geochemical behaviours of REEs within weathered metamictized granitic bedrock profile from Western Peninsular Malaysia

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Abstract: Rare earth elements (REEs), an important group of non-energy minerals, are vital to industrialized societies worldwide. Southeast Asian granitic belts are potential sources of ion-adsorption REE clays comprising large weathered granitic crusts that often have high-grade ion-adsorbed REEs. Characterization studies were conducted on representative samples from two sites, namely Lumut (LU) and Telok Murok (TM), located within the Malaysian Western granite belt. In both profiles, parent rocks were documented as medium-grained mica (phlogopite)-rich, S-type, peraluminous, ilmenite-series granite with metamict texture. Quartz, K-feldspar, and mica were major minerals, while REE-bearing accessory minerals were apatite, allanite, monazite, xenotime, and zircon. Al_2O_3 and LOI contents increased with depth in both weathered profiles, whereas P_2O_5 tended to be constant. Long-tube halloysite/kaolinite are abundant clays in the upper portions of the profiles, whereas the lower parts were rich in short-tube halloysite with smectite. Moreover, the depletion of REE + Y (REY) content in horizon A (B1) was clear, whereas REY was abundant in horizon B and/or C. The maximum content of REY could reach up to approximately 850 and 2350 ppm in horizon B2 and/or C in the LU and TM sites, respectively. Total REE content of the weathered crust was relatively elevated compared with that of the parent rocks (3–7 times) in the lower portions of both sites due to "high adsorption capacity" of abundant clay minerals in the deep profiles. Enrichment in LREE and HREE was indicated in the LU and TM sites, respectively. Trial leaching experiments with high-grade samples from both sites were conducted using ammonium sulfate. High recovery in the results proved REE adsorption by the clays in the lower parts of the profiles.

The Sejana Project, Kelantan
History of mineral exploration and discoveries

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Abstract: The Sejana Project is located in the State of Kelantan, district of Jeli. It is situated along the main peninsular Malaysia central gold belt that hosts the majority of the country primary gold deposits and mines, including the nearby Ulu Sokor which is controlled by CNMC (SGX listed) and is currently the largest gold producer of Malaysia. The Sejana Project covers approximately 8,000 acres in a single piece of land entirely occupied by a palm oil plantation belonging to PPLRNK a state entity with which the group entered into an exploration agreement.

Almost 10 years of regional then detailed exploration led to the identification of at least five primary targets each with a different geological setting and potentially economic resources of precious metals (gold, silver) and/or base and industrial metals (including tungsten). One of the multi-minerals primary deposits has been the object of dense surface works and drilling (RC and diamond) and is currently at the stage of JORC compliant resources estimate. The other targets have been the object of preliminary surface and shallow drilling as well as ground geophysics. Several alluvial gold deposits were also identified and explored in the property.

Development of rare earth mineral industries in Malaysia: Challenges and way forward for educational sector

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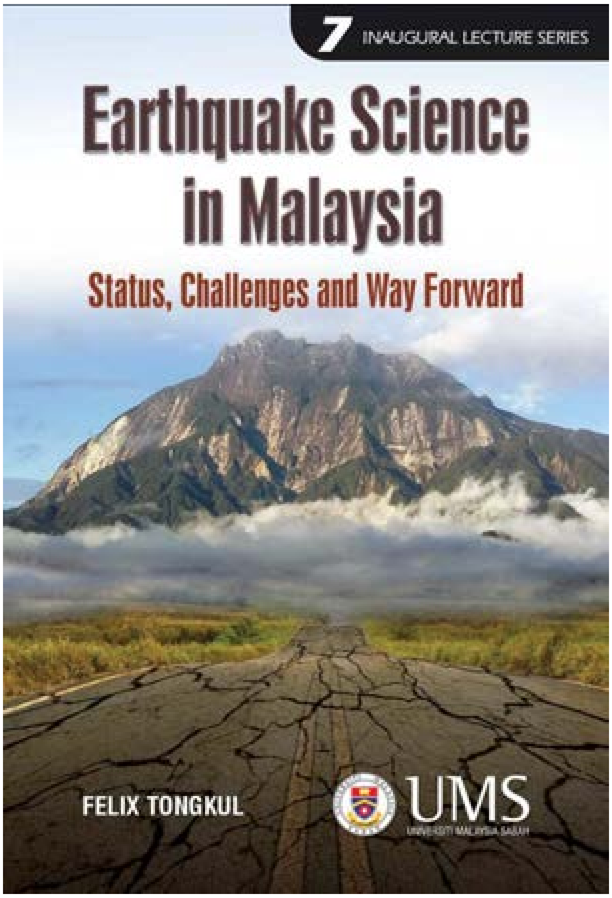
Abstract: As per Global Market Insight Inc., the rare earth mineral market was estimated at USD 13.2 billion in 2019 and is expected to hit nearly USD 19.8 billion by 2026 registering a Compound Annual Growth Rate (CAGR) of 10.8% from 2020 to 2026. In short, this trending marks the strong indication that it has become increasingly significant in the constant evolving economy worldwide. Meanwhile, China has been the leading undisputed producer and supplier of all spectrum of rare earths to the world over than 20 years from 1980s. More than 80% of the geographical global distribution, which covers rare earth separation, refining, purification, metal making, and component manufacturing industries are mainly concentrated within China alone. Thus, developing a complete supply chain outside China has been always desirable and would attract massive investment globally. In this regard, Malaysia should take an active role, as well as perhaps, gradually becoming as one of key resource suppliers using its own domestic mineral capacity. The establishment of the rare earth advanced processing plant by Lynas Corporation in Gebeng has prompted a more detailed evaluation of the rare earth business opportunities, especially on how best can Malaysia as a country participate strategically. In this light, a comprehensive feasibility study on the development framework in all relevant phases comprising of upstream, mid-stream and downstream of this industry, which tapping out the domestic supply should be initiated urgently, encouraged but cautiously analysed. At the core, educational sector from both public and private entities, is one of the major shareholder segments which demand special attention in ensuring a sustainable development can be realised. This is of particularly important as it mainly contributes in generating the critical local workforce masses as well as accommodate productive technology innovation that should uniquely supports the circular economic model of the industry. Otherwise, the expected socio economic growth which potentially brought by this particular resource will not be lasting while the country is struggling with the aggressive environmental mutilation, and not to mention, weak ethical practises. Malaysia in general, still has a long way ahead in this line of development, nonetheless, with supportive government policy and incentives which are embedded into a comprehensive set of academic program, the idea and opportunity of becoming a leading nation supplier, at least in the regional level, should be appreciated as well as practically achievable.

Live-streamed Public Lecture

"Earthquake science in Malaysia – Status, challenges and way forward"

FELIX TONGKUL

Universiti Malaysia Sabah, Malaysia

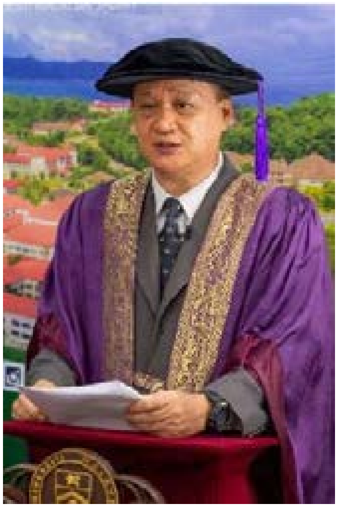


A live online public lecture, via Facebook and Youtube to educate the public on earthquake science in Malaysia was held on the 18 November 2020 by Universiti Malaysia Sabah (UMS). This is the seventh public lecture series organised by the university and the first one carried out live.The public lecture was given by Prof. Dr. Felix Tongkul, who heads the Natural Disaster Research Centre of the Faculty of Science and Natural Resources, UMS. He was accompanied by the Vice Chancellor of Universiti Malaysia Sabah, Prof. Datuk ChM Dr. Taufiq Yap Yun Hin; the Deputy Vice Chancellor (Academic & International), Prof. Dr. Rasid Mail and the Dean of Faculty Science and Natural Resources, Prof. Dr. Baba Musta. After a brief introduction about the event by the MC, Dr. Zulherry Isnain, the public lecture started with a 10 minutes video presentation tracing the academic journey of the speaker. This was followed by an introduction of the speaker by Prof. Taufiq, the Vice Chancellor of Universiti Malysia Sabah. Prof. Felix then gave his 40 minutes lecture covering three main topics, the status, key challenges faced and the way forward for earthquake science in Malaysia. He concluded by saying that significant earthquake (of magnitude 5-6) will continue to occur in Malaysia but will be limited to certain areas in Sabah, around Ranau, Lahad Datu, Kunak and Kudat. He also said that while earthquake cannot be prevented, levels of risk can be reduced or eliminated with proper understanding of how earthquake interacts with the surrounding. A detailed seismic hazard map in the high-risk areas is urgently needed. He added that earthquake-prone areas like Sabah should seriously start implementing the newly developed earthquake resistance building code (Eurocode-8). After the lecture, the speaker presented his book entitled "Earthquake Science in Malaysia – Status, Challenges and Way Forward" to the Vice Chancellor of Universiti Malaysia Sabah. A PDF copy of this book can be downloaded for free at *https://www.ums.edu.my/ndrc/en/publication/books/201-ebook-earthquake science-in-malaysia-status-challenges-and-way-forward*.

The lecture was well-received by the public, whereby Facebook and Youtube recorded 6.8k and 522 views, respectively, during the live event.

Dr. Zulherry giving a brief introduction about the public lecture event.

The Vice Chancellor of Universiti Malaysia, Prof. Taufiq introducing the speaker, Prof. Felix.



Prof. Felix delivering his public lecture entitled "Earthquake Science in Malaysia – Status, Challenges and way Forward".

Prof.Taufiq receiving a book entitled "Earthquake Science in Malaysia – Status, Challenges and Way Forward" from Prof. Felix.

DALAM KENANGAN

Tajul Anuar Jamaluddin: Pemangkin geologi kejuruteraan di Malaysia

Tajul Anuar Jamaluddin: Advocator of engineering geology in Malaysia

Kehidupan awal dan pendidikan

Allahyarham Prof. Madya Dr. Tajul Anuar Jamaluddin dilahirkan pada 10 September 1964 di Batu Gajah, Perak. Beliau merupakan anak kedua daripada lima orang adik beradik dan dibesarkan sepenuhnya oleh ibu bapanya, En. Jamaluddin bin Mat Sharif dan Pn. Rahemah binti Daud di Tanjung Tualang, Perak; kawasan yang sangat terkenal dengan pertanian, penternakan dan perlombongan bijih timah sekitar tahun 1970-an. Ayah beliau bekerja di syarikat perlombongan bijih timah di Tanjung Tualang sebelum berkhidmat di FELCRA Sungai Durian, manakala ibunya seorang suri rumah. Beliau dibesarkan dalam suasana, budaya dan adat kampung yang mencetuskan minat beliau yang mendalam dalam bidang pertanian dan penternakan. Keadaan inilah yang menjadikan beliau bukan sahaja dikenali dalam kalangan ahli geologi, tetapi turut dikenali dalam kalangan pengusaha penternakan terutamanya kerbau dan pertanian.

Dr. Tajul memulakan pendidikan peringkat rendah di St. Paul's School, Tanjung Tualang (kini SK St. Paul) dari tahun 1971 hingga 1976. Pada tahun 1977, beliau memasuki peringkat menengah rendah di SM Dato' Bendahara C.M. Yusuf, Tanjung Tualang hingga tamat Sijil Rendah Pelajaran (SRP). Setelah itu, beliau menyambung pengajian peringkat menengah atas di SMK Sultan Yusuf, sekolah aliran Inggeris pertama di Batu Gajah, Perak hingga tamat Sijil Pelajaran Malaysia (SPM) pada tahun 1981. Selepas menamatkan SPM, beliau mendapat tawaran melanjutkan pelajaran dalam bidang pertanian di Universiti Pertanian Malaysia (UPM), Sabah. Walau bagaimanapun, beliau membatalkan hasrat untuk menyambung pelajaran dalam bidang yang diminatinya atas faktor-faktor tertentu. Beliau kemudian melanjutkan pengajian di peringkat persediaan di Kolej Matrikulasi Universiti Kebangsaan Malaysia (UKM) di Sekolah Menengah Sultan Abdul Halim, Jitra, Kedah dari tahun 1982 hingga 1983.

Pada tahun 1984, beliau memulakan pengajian peringkat sarjana muda (BSc.) di UKM (tamat 1987) dan kemudiannya menyambung pengajian di peringkat Sarjana Sains Kejuruteraan Geologi (MSc.) dan tamat pada tahun 1990. Pada masa yang sama, beliau turut berkhidmat sebagai tutor sementara di Jabatan Geologi UKM semasa tempoh pengajian sarjana. Setelah itu, beliau memulakan kerjaya sebagai ahli geologi kejuruteraan (*engineering geologist*) di Malaysia International Consultant (kini Minconsult Sdn Bhd) selama satu tahun.

Pengajar dan penyelidik

Pada tahun 1991, beliau mendapat tawaran dalam program Skim Latihan Anak Bumiputera (SLAB) dari Universiti Malaya dan membolehkan beliau melanjutkan pelajaran di peringkat Doktor Falsafah (PhD) dalam bidang Geologi Struktur di University of Wales Aberystwyth, United Kingdom dan tamat pada tahun 1997. Sekembalinya beliau ke tanah air setelah tamat pengajian, beliau berkhidmat di Jabatan Geologi, Universiti Malaya sebagai pensyarah (1997 hingga 2004) dan Profesor Madya (2004 hingga 2006) sebelum berhijrah ke Jabatan Geosains dan Petroleum Geologi, Universiti Teknologi Petronas (UTP) pada Jun 2006 hingga Februari 2007. Bagai "sirih pulang ke gagang", beliau kembali ke UKM dan berkhidmat sebagai pensyarah di Jabatan Geologi pada Mac 2007 hingga akhir hayat beliau pada 2 Ogos 2020.

Foto 1: Foto-foto sekitar pengajian di Universiti Kebangsaan Malaysia.

Bidang kepakaran beliau meliputi bidang Geologi Kejuruteraan, Geologi Struktur, Tektonik, dan Geobencana. Minat dan kecenderungan penyelidikan beliau pula meliputi bidang kestabilan cerun batuan, tanah runtuh, sesar aktif dan gempa bumi, tsunami, geobahaya terrain semulajadi, dan pengurusan/pengurangan risiko geobencana. Sejak menjadi pensyarah, Dr Tajul juga telah memberikan khidmat kepakaran dalam lebih 110 buah projek perundingan kepada agensi/institusi kerajaan (cth : JMG, JKR, JAS, JPBD, JPKT, IKRAM) dan industri swasta sama ada di peringkat kebangsaan mahupun luar negara. Pengalaman, data dan hasil kajian perundingan ini melibatkan lebih daripada 200 laporan teknikal yang tidak atau masih belum diterbitkan.

Melalui pengalaman, kepakaran dan ilmu beliau, Dr Tajul juga terlibat secara langsung dalam kira-kira 50 projek penyelidikan di universiti dengan penghasilan sejumlah 43 kertas jurnal berwasit, lebih 200 kertas kerja persidangan, forum, seminar dan pembentangan, 5 buah penerbitan buku, 27 bab/bahagian dalam buku dan sejumlah kertas ucaptama, polisi serta garis panduan.

Sehingga ke akhir hayat beliau, Dr Tajul masih menjadi Felo Penyelidik di Pusat Kajian Bencana Alam UMS dan LESTARI UKM, serta menjadi pemeriksa luar tesis peringkat Sarjana dan PhD bidang geologi kejuruteraan/ geoteknik untuk IPTA (UM, USM, UTM, UMS, UMK, dll). Beliau juga sering diundang untuk wacana program TV, radio dan akhbar bagi memberikan ulasan berkaitan peristiwa-peristiwa geobencana tanah runtuh, banjir lumpur, gempa bumi dan tsunami yang berlaku di Malaysia dan rantau sekitarnya.

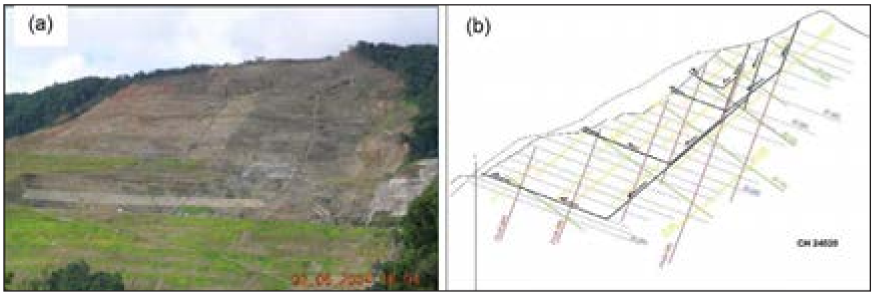
Kerja-kerja perundingan

Dr Tajul merupakan seorang tokoh geologi kejuruteraan yang disegani di Malaysia. Khidmat dan kepakaran beliau sering kali ditagih dalam menyelesaikan kes-kes geologi kejuruteraan khususnya melibatkan tanah runtuh dan kegagalan cerun. Hingga kini, beliau terlibat dalam sekurang-kurangnya 79 projek perundingan. Kerja-kerja perundingan yang beliau jalankan meliputi pelbagai pemain industri sama ada kejuruteraan (JKR, IKRAM dan GAMUDA), perancangan pembangunan (Plan-Malaysia) atau pemaju. Antara kes kegagalan cerun utama yang disiasat adalah seperti Gunung Pass di Pos Selim, Perak (Rajah 1) dan Empangan Kelalong di Bintulu, Sarawak.

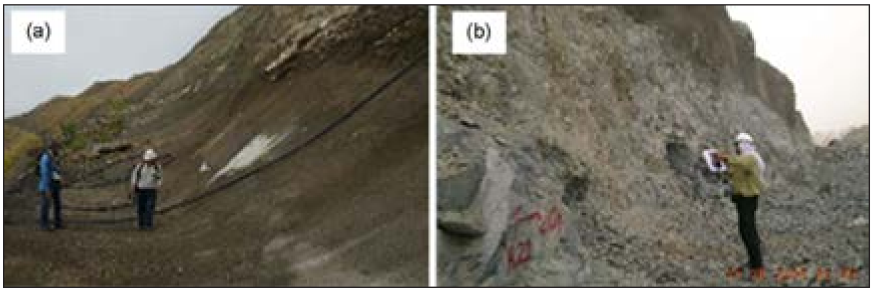
Kerja perundingan beliau turut meliputi projek-projek dari luar negara, seperti Laos dan Arab Saudi (Rajah 2b). Hal ini membuktikan bahawa kepakaran beliau dalam bidang geologi kejuruteraan dan geobencana bukan sahaja diiktiraf di Malaysia, malah khidmatnya diperlukan di luar negara.

Kepakaran beliau kemudiannya dimanfaat untuk membentuk dasar kerajaan khususnya dalam perancangan pembangunan dan kejuruteraan. Antaranya adalah seperti penglibatan beliau dalam "Kajian Penyelidikan Geobencana dalam Perancangan Pembangunan" dan "Rancangan Tempatan Daerah Cameron Highland 2015-2030" untuk Jabatan Perancang Bandar dan Desa (PlanMalaysia), "*Preparation of EIA Guidelines for Housing and New Township Development (Geological Section)*" untuk Jabatan Alam Sekitar (DOE), serta "*Guidelines for Landslide Vulnerability Assessment And Development of Risk Index for Critical Infrastructure (CI) In Malaysia*" untuk *Construction Research Institute Of Malaysia* (CREAM), sebuah agensi di bawah Construction Industry Development Board (CIDB).

Selain kerja-kerja perundingan melibatkan geologi kejuruteraan, beliau juga melibatkan diri dalam kerja penyiasatan berkaitan geologi, seperti analisis petrografi dan pemetaan geologi. Contoh kerja perundingan beliau dalam bidang



Rajah 1: Fotograf kegagalan cerun di Gunung Pass yang diambil pada tahun 2004 (a) dan lakaran skematik pengaruh struktur geologi terhadap kegagalan (b) yang ditafsir oleh Dr Tajul (Asbi *et al*., 2005).



Rajah 2: Kerja perundingan Dr Tajul di lapangan melibatkan (a) Jalan Pos Selim – Blue Valley untuk JKR, dan (b) di Makkah, Arab Saudi untuk Jabal Omar Development Project. (Gambar daripada koleksi Dr Tajul).

ini adalah seperti "Pendekatan Geologi Dalam Kajian Batu Bersurat Piagam Terengganu" untuk Lembaga Muzium Negeri Terengganu.

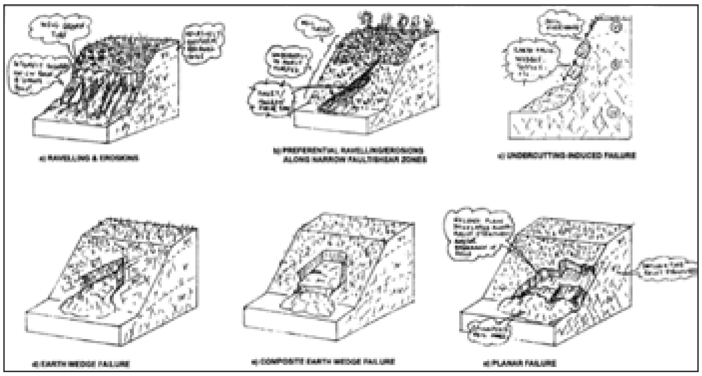
Sumbangan bermakna kepada geologi kejuruteraan

Dalam tempoh 23 tahun sebagai pakar geologi kejuruteraan di Malaysia, Dr Tajul Anuar Jamaluddin telah meninggalkan legasi besar terhadap bidang ini yang membentuk pemahaman ahli geologi terhadap punca, proses dan impak aktiviti geologi kejuruteraan. Dua topik yang sering ditekankan dalam perbincangan beliau ialah "Pengaruh Struktur Geologi dan Luluhawa dalam Kegagalan Cerun" dan "Tanah Runtuh Pendam Lama".

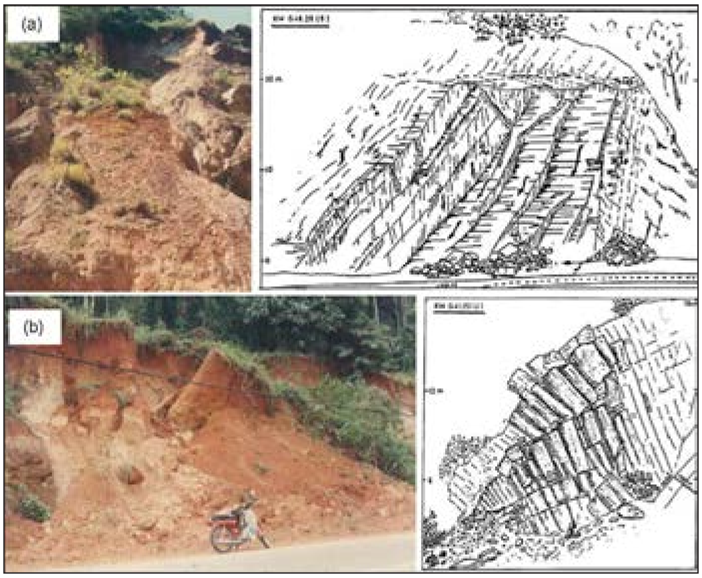
Pengaruh Struktur Geologi dan Luluhawa dalam Kegagalan Cerun

Berdasarkan pelbagai penyelidikan sejak kajian Sarjana beliau, Dr Tajul berpendapat bahawa struktur geologi dan luluhawa memainkan peranan penting dalam mempengaruhi kegagalan cerun di Malaysia. Beliau menekankan bahawa struktur geologi masih wujud dalam jasad terluluhawa Gred IV-V sebagai struktur relik dan berpotensi membentuk satah kegagalan cerun. Kajian kes berkaitan yang pernah diterbitkan termasuklah kegagalan cerun di Lebuh Raya Timur-Barat antara Gerik dan Jeli (Tajul Anuar Jamaluddin, 1991), Jalan Tg. Siang, Kota Tinggi, Johor (Tajul Anuar Jamaluddin & Fauzi, 2000) dan di Empangan Kelalong, Bintulu, Sarawak (Tajul Anuar Jamaluddin, 2004).

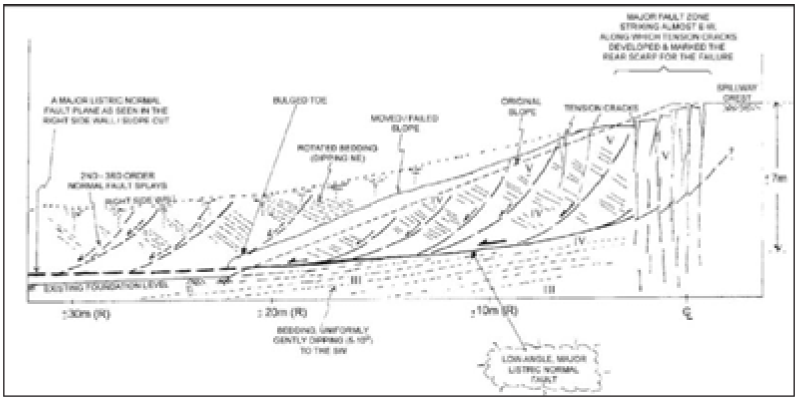
Beliau menjelaskan bahawa struktur geologi di dalam jasad yang terluluhawa menjadikan jasad cerun tersebut bersifat tidak selanjar dan tidak gagal akibat sifat geoteknikal bahan geologi cerun semata-mata. Sebaliknya, struktur relik ini membentuk satah lemah yang membenarkan pergerakan berlaku (secara planar atau baji), atau membentuk zon lemah yang lebih mudah teluluhawa dan terhakis berbanding kawasan lain di dalam jasad cerun yang sama. Rajah 3, 4, dan 5 menunjukkan penerangan beliau dalam kajian kes yang menunjukkan pengaruh struktur geologi terhadap kegagalan jasad cerun.



Rajah 3: Pengaruh struktur geologi relik terhadap kegagalan cerun yang terluluhawa. (a) Bukaan dan hakisan, (b) Bukaan/hakisan berbeza pada zon sesar/rich sempit, (c) Kegagalan disebabkan oleh undercut, (d) Kegagalan baji tanah, e) kegagalan baji tanah komposit, dan (f) kegagalan planar (Tajul Anuar Jamaluddin & Fauzi, 2000).



Rajah 4: Kegagalan cerun akibat struktur relik di Lebuh Raya Timur-Barat (Tajul Anuar Jamaluddin, 1991). (a) adalah fotograf dan lakaran kegagalan baji manakala (b) adalah fotograf dan lakaran kegagalan terbalikan. Kesemua kegagalan berlaku dalam jasad tanah (Gred IV-V) namun dipengaruhi oleh kehadiran struktur geologi relik.



Rajah 5: Kegagalan pada asas (foundation) alur limpah Empangan Kelalong akibat kehadiran sesar listrik pada dasar struktur (Tajul Anuar Jamaluddin, 2004). Kegagalan ini tidak berlaku dalam jasad terluluhawa tinggi, sebaliknya berlaku dalam jasad batuan bergred II-III. Hasil siasatan mendapati kerja-kerja tanah telah mendedahkan sesar listrik tersebut sekali gus mengaktifkan semula sesar pada sudut kegagalan yang rendah.

Sumbangan Dr Tajul Anuar Jamaluddin dalam bidang ini amat penting kerana insiden kegagalan melibatkan struktur geologi relik dalam jasad terluluhawa sering direkodkan tetapi mekanisme kegagalan berkenaan kurang difahami. Hal ini ditambah lagi dengan iklim tropika yang dialami Malaysia menjadikan jasad cerun terluluhawa adalah fenomena biasa dalam kerja geoteknikal. Beliau menggunakan fotograf dan lakaran terperinci yang efektif untuk menerangkan faktor, mekanisme dan cadangan penyelesaian yang berkaitan. Konsep dan kaedah beliau dalam mengenal pasti pengaruh struktur geologi terhadap kegagalan cerun merupakan sebuah legasi yang perlu dimanfaatkan oleh generasi ahli geologi yang seterusnya.

Tanah runtuh pendam lama

Tanah runtuh pendam lama merupakan fenomena yang turut menjadi fokus kajian Dr Tajul Anuar Jamaluddin. Tanah runtuh seperti ini ditafsir oleh beliau menerusi fitur geomorfologi daripada peta topografi dan disahkan dengan cerapan lapangan. Walaupun tanah runtuh tersebut sudah tidak lagi aktif, namun aktiviti manusia khususnya yang melibatkan kerja-kerja tanah mampu menyebabkan tanah runtuh pendam diaktifkan semula.

Antara kerja awal beliau dalam kes ini ialah sistem tanah runtuh di Kundasang, Sabah (Komoo *et al*., 2005). Beliau mendapati bahawa pergerakan tanah yang menyebabkan kerosakan infrastruktur adalah disebabkan tanah runtuh berskala besar yang berlaku pada kadar perlahan. Ketika itu, tanah runtuh tersebut dikategorikan sebagai aktif kerana pergerakan berlaku secara berterusan dan bukannya sebagai pengaktifan semula tanah runtuh pendam lama, malah tanah runtuh berskala besar bukanlah sesuatu yang biasa berlaku dan kes di Kundasang dianggap unik ketika itu.

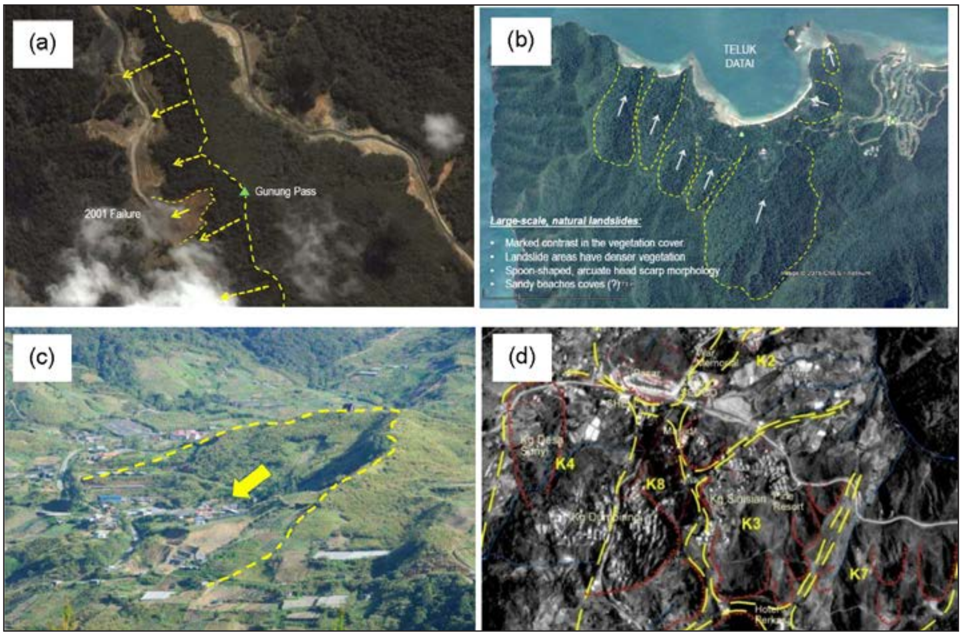
Walau bagaimanpun, setelah beliau mula menyiasat lebih mendalam berkenaan teori ini, beliau mula mengkaji semula kes-kes yang pernah berlaku sebelum ini. Beliau mendapati kebanyakan kegagalan cerun bersaiz besar adalah berpunca daripada pengaktifan semula tanah runtuh pendam lama. Antara contoh kajian kes yang ditafsir berpunca daripada fenomena tanah runtuh pendam lama adalah seperti di Gunung Pass (Rajah 6a), kawasan Teluk Datai, Langkawi (Rajah 6b), dan kompleks tanah runtuh di Kundasang (Rajah 6c dan 6d).

Berdasarkan penemuan tersebut, Dr Tajul mula aktif mentafsir potensi tanah runtuh pendam lama dalam penyiasatan geologi kejuruteraan berikutnya. Selain imej satelit, beliau turut menggunakan teknik penderiaan jauh lain seperti IfSAR dan LiDAR (Rajah 7a). Bukti lapangan seperti kehadiran endapan runtuhan (koluvium) dan morfologi tanah runtuh relik menyokong tafsiran beliau. Antara penyelidikan beliau yang utama adalah di Cameron Highlands pada tahun 2018 (Rajah 7b – 7c) Beliau mendapati aktiviti manusia yang pesat di dalam kompleks tanah runtuh pendam lama menjadi antara penyumbang kejadian tanah runtuh baharu saban tahun.

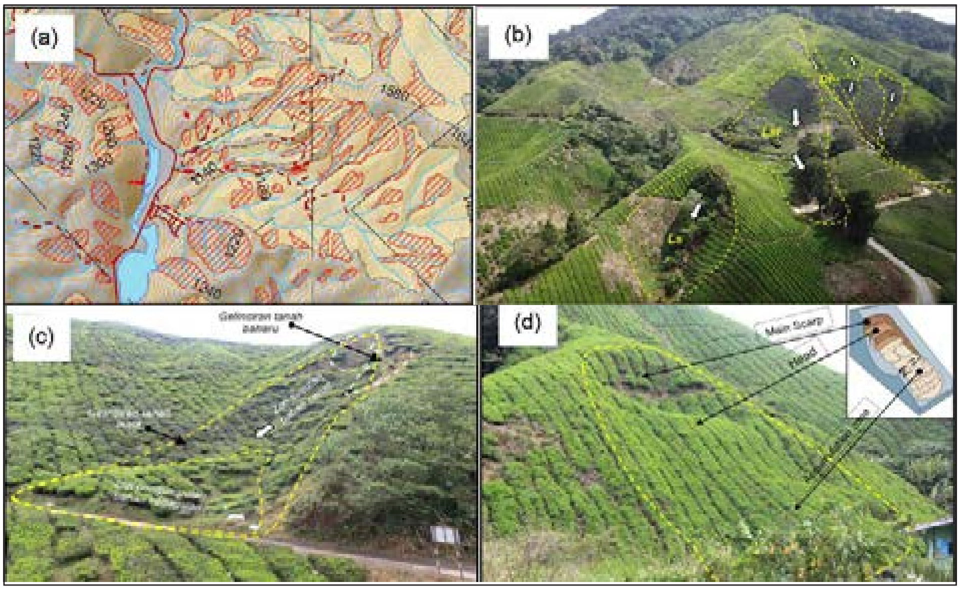
Jurucakap berhubung bahaya dan bencana geologi

Dr Tajul amat dikenali sebagai pengulas kepada kejadian-kejadian bencana geologi, seperti tanah runtuh, banjir, gempa bumi dan jatuhan batuan. Beliau sering kali dipanggil ke rancangan-rancangan diskusi di televisyen, radio, akhbar dan media elektronik untuk ditemuramah dan berkongsi kepakaran serta pengalaman. Kejadian bencana tanah runtuh yang menjadi topik hangat di Malaysia, seperti tanah runtuh di sekitar Bukit Antarabangsa pada tahun 2008, Hulu Langat pada tahun 2011 dan Cameron Highlands turut diulas oleh Dr Tajul. Komen dan pendapat beliau sering kali tular di dada akhbar dan menjadi kebanggaan komuniti geologi, terutamanya berkenaan dengan kepentingan mamahami prinsip asas geologi yang perlu diambil kira dalam perancangan pembangunan.

Usaha ini seterusnya dapat memasyarakatkan ilmu bencana geologi kepada masyarakat awam. Pandangan yang diutarakan oleh beliau sering kali bersifat neutral, kritis dan berterus terang. Beliau berpandangan bahawa bencana geologi, seperti tanah runtuh dan jatuhan batuan dapat dielakkan sekiranya penyiasatan awal secara terperinci di kawasan



Rajah 6: Tafsiran tanah runtuh pendam lama di Gunung Pass (a), Teluk Datai, Langkawi (b), dan Kundasang, Sabah (c & d) (Tajul Anuar Jamaluddin, 2015, Komoo *et al*., 2005) berdasarkan imej satelit dan fotograf lapangan. Fitur-fitur geomorfologi yang ditafsir sebagai tanah runtuh pendam lama menjadi antara punca tanah runtuh baharu apabila aktiviti manusia berlaku di kawasan berkenaan.



Rajah 7: Tafsiran tanah runtuh pendam lama oleh Dr Tajul Anuar Jamaluddin pada IfSAR (a) dan cerapan lapangan (b-d) di Cameron Highlands, Pahang.

berpotensi berlaku kejadian ini dilaksanakan mengikut garis panduan serta mengambil kira aspek geologi semula jadi bahan, geologi struktur dan geomorfologi di kawasan pembangunan.

Selain faktor bahan geologi semula jadi dan geologi struktur yang menyebabkan tanah runtuh, Dr Tajul juga berpendapat bahawa kaedah kerja tanah yang tidak sempurna juga menjadi salah satu faktor kejadian tanah runtuh. Hal ini dilihat melalui hasil pentafsiran fotoudara yang telah dijalankan oleh beliau di sekitar kawasan Bukit Antarabangsa, Selangor. Beliau berpendapat bahawa sekitar tahun 1980-an dan 1990-an, pembangunan sangat pesat di kawasan atas bukit dan kawasan tanah tinggi. Bahan-bahan daripada aktiviti kerja tanah, tarahan dan potongan bukit dilonggokkan dan ditambak ke sisi cerun yang membentuk cerun tambakan yang tidak sempurna dan longgar (*tip-filled slope*). Hal

Rajah 8: Temubual terakhir Dr Tajul bersama Astro Awani berbincang tentang kejadian tanah runtuh di Taman Kelab Ukay pada 30 May 2020.

ini seterusnya menjadi potensi untuk berlakunya kejadian tanah runtuh, selain faktor hujan, perpaipan yang tidak sempurna serta longkang saliran yang tidak diselenggara dengan baik.

Amalan kebiasaan dalam kajian kesesuaian pembangunan yang terlalu bertumpu kepada sempadan projek sahaja tanpa mengambil kira keseluruhan kawasan yang berpotensi menjadi faktor kepada kejadian tanah runtuh turut menjadi kerisauan beliau. Beliau menyarankan ahli geologi profesional perlu dilibatsamakan dalam projek-projek pembangunan supaya maklumat sejarah kejadian tanah runtuh silam, proses-proses permukaan bumi yang tidak bersempadan serta maklumat geologi diambil kira dalam penyediaan susun atur atau rekabentuk suatu pembangunan.

Dr Tajul juga sering menekankan pentingnya garis panduan khusus yang jelas bagi aktiviti pembangunan di kawasan tanah tinggi yang mesti dipatuhi oleh semua pemaju pembangunan atau pertanian agar kelestarian pembangunan tanah tinggi terjamin. Beliau juga menegaskan bahawa pihak penguatkuasa boleh menggunakan khidmat nasihat jabatan berkaitan untuk memberikan khidmat nasihat berkaitan dengan undang-undang sedia ada untuk bertindak sekiranya garis panduan yang ditetapkan tidak dipatuhi.

Selain itu, Dr Tajul turut menyumbangkan kepakaran beliau ketika kejadian tanah runtuh di Madrasah At-Taqwa, Hulu Langat pada tahun 2011. Beliau telah membuat pemantauan, terutamanya ketika proses mencari dan menyelamat dijalankan.

Penghubung antara akademik dan industri

Dalam suasana aliran pemikiran akademik dan industri selalunya tidak selari di Malaysia, Dr Tajul merupakan salah seorang ahli akademik yang telah berjaya menjadi penghubung antara dua sektor ini. Beliau mudah didampingi oleh penggiat industri lantaran sikap beliau yang tidak pernah lokek berkongsi ilmu.

Beliau sering bekerjasama secara aktif dan memberikan khidmat nasihat kepada penggiat industri dalam melakukan kerja-kerja perundingan. Skil cerapan di lapangan, terutama dalam mengenal pasti struktur geologi amat berguna kepada penggiat industri untuk menghasilkan cerapan yang tepat.

Foto 2: Dr Tajul menjadi penghubung antara bidang penyelidikan/akademik dan industri. a) Dr Tajul kerap menjadi pakar rujuk terutama dalam kajian konsultasi tanah runtuh. b) Dr Tajul bersama pasukan Geomapping Technology ketika menjalankan kajian Pemetaan Geologi Terain di Cameron Highlands. c) Dr Tajul memberi penerangan dalam bentuk diagram skematik perihal morpfologi tanah runtuh. d) Dr Tajul bersama memberi perkongisan dapatan kajian pemetaan geologi terain di Cameron Highland kepada JMG anjuran Geomapping Technology.

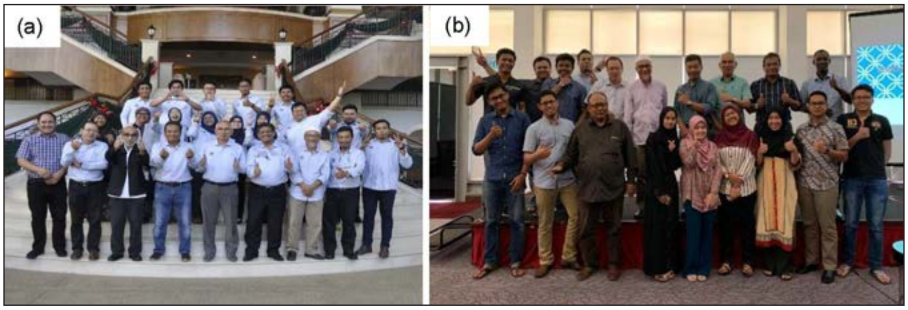


Foto 3: Sekitar aktiviti Dr Tajul bersama Geomapping Technology Sdn. Bhd. (a) Aktiviti pelan perniagaan yang turut dihadiri Dr Tajul pada awal Januari 2020. (b) Pelan perniaagaan pada tahun 2019.

Dr Tajul menggunakan prinsip-prinsip asas dan juga ilmu-ilmu asas geologi dalam menyelesaikan permasalahan geologi kejuruteraan. Prinsip dan ilmu asas geologi ini selari dengan konsep-konsep geologi kejuruteraan terkini yang dibincangkan di peringkat antarabangsa, seperti model geologi kejuruteraan (engineering geological model), pendekatan geologi mutlak (total geological approach) mahupun geomorfologi kejuruteraan (engineering geomorphology)

Beliau juga akan menggunakan hasil-hasil kerja perundingan beliau untuk dijadikan bahan pengajaran kepada pelajar-pelajar beliau supaya pelajar-pelajar lebih terdedah kepada kajian kes sebenar.

Epilog (oleh Abd Rasid Jaapar)

Pertama kali saya berjumpa Dr Tajul di Jabatan Geologi, UKM sesi 1989/90, semasa saya di tahun 2 dan beliau menjadi tutor kelas geologi struktur iaitu ketika beliau menyelesaikan pengajian peringkat master. Ketika itu, beliau telah menunjukkan ciri-ciri pengajar yang hebat. Semasa kelas amali geologi struktur, penerangan beliau kepada kelas amat jelas dan mudah difahami. Kami menjadi kawan baik kerana kami sering berborak santai selepas kelas amali pada sebelah petang.

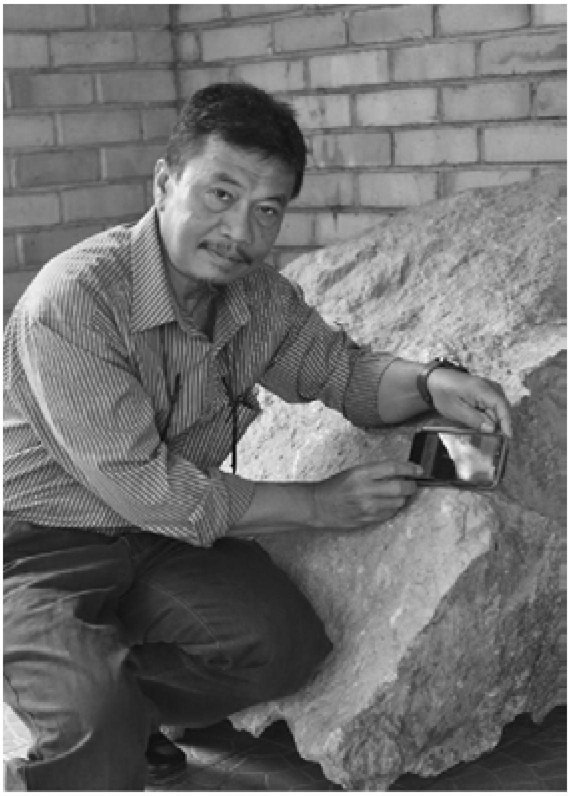
Persahabatan terputus seketika ketika beliau menyambungkan pelajaran peringkat PhD di Wales, United Kingdom.

Kami kembali berhubung ketika beliau mengajar di UM. Ketika itu saya bekerja di Soils & Foundations Sdn Bhd, sebuah syarikat geoteknik di Jalan Klang Lama. Kami sering berhubung dan bertukar padangan tentang kerja-kerja geoteknikal, terutamanya penyiasatan tapak pada awal penglibatan beliau dalam kerja-kerja perundingan ketika di UM.

Adakala saya membantu beliau untuk mendapatkan data-data lubang gerudi yang hampir dengan kawasan kajian beliau. Ada sekali dua, saya membantu beliau melakukan pemetaan di lapangan. Bagi saya, kerjasama ini lebih kepada pengajaran dan pembelajaran ketika itu. Sering kali beliau mengajak saya untuk menyambung pelajaran di peringkat sarjana bawah seliaan beliau. Selalunya saya jawab belum bersedia.

Kami menjadi lebih rapat apabila beliau berpindah ke Sungai Ramal dan akhirnya ke Bandar Baru Bangi, tempat di mana saya juga menetap.

Sekitar tahun 1996-97, saya terlibat dengan beliau dalam projek pemetaan geologi kejuruteraan kegagalan cerun di Tol Plaza Senai, Lebuhraya Lintasan Kedua Malaysia-Singapura beberapa bulan sebelum lebuhraya beroperasi, Ketika itu saya bekerja di Soil Centralab Sdn Bhd. yang merupakan pemegang kontrak kerja berkenaan. Projek ini adalah antara projek perundingan yang memberikan kepuasan kepada beliau kerana beliau berjaya membuktikan hubungan antara geologi dan tanah runtuh, terutamanya kewujudan struktur relikta dan pengaliran air di satah-satah ini.



Allahyarham Profesor Madya Dr. Tajul Anuar Jamaluddin

Projek lain yang melibatkan kami berkerja bersama-sama adalah pada sekitar tahun 2008 iaitu projek pemetaan geologi kejuruteraan berkala di cerun batuan granit di Cangkat Jering, Lebuhraya Utara Selatan. Kerja ini juga melibatkan saudara Ibrahim Lah, Syed Lukman Hakim dan Ahmad Lufti. Kesemua mereka telah menjadi usahawan geologi yang berjaya. Namun begitu, penglibatan saya cuma separuh jalan kerana saya mendapat tawaran kerja dalam bidang industri minyak dan gas.

Projek terakhir yang melibatkan kerjasama antara kami adalah ketika saya sudah bersama dengan Geomapping Technology Sdn Bhd iaitu projek Pemetaan Geologi Terain seluruh Cameron Highlands dan juga projek penghasilan *Guideline for Landslide Vulnerability Assessment and Risk Analysis for Critical Infrastructures (CI) in Malaysia.*

Beliau memang seorang yang cekap dan teliti dari segi penafsiran imej-imej udara dan juga ketika melakukan cerapan struktur-struktur geologi di lapangan.

Sering kali juga kami berdebat kerana perbezaan dari segi pendekatan dan pemahaman, terutama selepas saya menamatkan pengajian master saya, tetapi selalunya perbezaan pendapat dan pandangan ini adalah untuk menambah lebih pemahaman terhadap subjek.

Selain dari geologi, beliau juga amat berminat dalam bidang pertanian terutamanya penternakan. Memang banyak penceritaan beliau kepada saya berhubung harapan beliau dengan bidang ini juga selain bidang geologi.

Sesungguhnya pemergian beliau adalah satu kehilangan yang besar kepada komuniti geologi kejuruteraan di Malaysia. Semoga kau damai di sana sahabat dan sifu.

Al Fatihah untuk Allahyarham PM Dr. Tajul Anuar Jamaluddin (1964-2020).

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Oleh:
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NEW MEMBERSHIP

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1. Aini Husna Mohd Sofi
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3. Muhamad Zarif Adib Mohamed Shah
4. Nik Muhammad Adib Ramiz Yaaziz
5. Nurul Ain Che Zakaria
6. Nurul Neeta Syafika Muhd Zaki
7. Wan Nursyazana Syarah Wan Ismail

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1. Mohammad Azuan Ab Talib

From Full To Life Membership

1. Mohd Badzran Mat Taib

Petroleum Geoscience Work Group Q4 activities highlights

The Covid-19 pandemic has hit hard for everyone. We in the geoscience community are not spared. By now, many of us have adjusted to the life of the *new normal*—working from home, keeping to personal hygiene, social distancing. We in the Petroleum Geoscience Work Group had to search for different ways to keep the Geological Society of Malaysia fraternity engaged.

With travel restriction bans, the need to avoid communal congregation, there comes a rise in technology based application that allow us to stay connected. The geoscience community worldwide was quick to adapt, with all conferences, seminars, and talks switch to online mode. We were lucky to tap into the AAPG Asia Pacific network (among other various contributions) to share these programs with the Society.

The activities were kickstarted with Schlumberger Geoscience Technology Week (October 19^{th} – November 3^{rd}), where the company showcased latest enhancements and introduced new workflows to their many licensed software. No doubt that the Technology Week has benefited many in the petroleum geoscience industry, as Schlumberger's software are widely used in the industry.

In early November, Women's Global Leadership Conference in Energy was held virtually. The conference featured more than 75 speakers across four days of live event. Among noted speakers was PETRONAS' very own VP of Exploration, Emeliana Rice-Oxley*, who delivered a keynote speech on Tackling Indifference. Link to the keynote speech can be found here: https://www.youtube.com/watch?v=_bfkJs4YL-o&feature=youtu.be

Besides conferences, the PG Work Group also managed to share several small scale talks and webinar series; 1) AAPG Distinguish Lecture Program: Exploring the Limits of Seismic Interpretation Techniques through the use of Computational Stratigraphy Models, by Lisa Goggins (November 4^{th}), and 2) UNIMAS-IBEC Webinar Series: Ichnology A Sherlock's Job, by Dr. Jose Antonio Gamez Vintaned.

In addition to free virtual talks and conferences, we were also able to share a virtual event held by The Geological Society of London: Operations Geology in 2020 and Beyond—Traditional and Modern Approaches (November 4^{th} – 5^{th}). Although not a free event, this conference was targeted to the niche group of operation geologists, who wished to share and discuss new approaches and advancements of technology in real-time drilling, as well as digitalization efforts subsurface monitoring.

To the young energetic students community, the Petroleum Geoscience Work Group had proudly shared 2 events that they can participate: 1) AAPG Imperial Barrel Award 2021—an annual petroleum exploration competition for university students, to be held virtually for the first time, and 2) 3^{rd} School on Sandstone Diagenesis—an annual training program for budding sedimentologists jointly organized by International Association of Sedimentologists and PetroArc International.

The Petroleum Geoscience Work Group will continue to share upcoming virtual events from time to time. We urge the GSM community, in particular the students, should take full advantage of the virtual events being shared, as most of them are free. This is a great avenue for graduates and/or job seekers to equip themselves on the latest industry topics. We hope that these small efforts will greatly benefit GSM members.

**Emeliana Rice-Oxley is a Life Member of the Geological Society of Malaysia*

Prepared by:
Maryam Syazana Dzulkefli
Petroleum Geoscience Work Group
GSM Council Member 2020-2021

"Wave Rock" of Malaysia – Hiking along Bukit Baginda Trail

Figure 1: This huge boulder stands prominently from the surrounding ground. Multiple boulder with distinctive fluting marks can be found littered along the path to the top. This one is the first boulder to be encountered, located just at the foot of the hill.

There have been recent interests on this strange rock formation, huge boulder measuring more than 20 m in height, with wavy surface that gives its "wave rock" name. Perched near the top of Bukit Baginda, this boulder exhibits parallel fluting marks, with each "flute" was estimated to be almost 0.5 m wide. Intrigued by the photographs, a trip to the boulder was set up to observe the boulder myself and investigating the geology behind this fascinating feature.

Getting there

Moving from Kuala Lumpur and surrounding area, expect a 2-hour drive to the starting point. Options are either through North-South Expressway via Senawang exit or LEKAS Highway to Senawang for those living in Kajang or Cheras. From Senawang, take the route to Kuala Pilah then straight to Batu Kikir. The starting area is marked with "Tanah Perkuburan Islam" signboard in Kampung Majau (roughly 15 minutes away from Batu Kikir), accessed via a small *kampung* road just before Kampung Majau Mosque.

Trekking up

For a seasoned hiker, 450 m up may seem easy but always be prepared with proper hiking gear including shoes as the trek may get slippery. One pleasant surprise is they prepared a public "*tongkat*" for anyone to use. Entry permit from Forestry Department is a must (RM 5.00 per head) and a forest ranger is stationed there on weekends. However, do expect additional charges by the locals on hikers (RM 6.00 per head) and vehicles (RM 5.00 per head).

The track is well defined with arrows, tapes and ropes, but if you are wary of getting lost in the jungle, there are locals who can act as guide (we came into contact with Cikgu Ramlan). From the starting point, it's a relatively easy hike through rubber plantation up until the first boulder, where it gets quite steep to the top. The hike to the top is estimated to be roughly 2 hours depending on weather.

The first boulder

Just two minutes into the hike through a relatively flat rubber plantations, a huge boulder was encountered

Figure 2: The first boulder at the bottom of hill as seen from aerial view. Its distinctive fluting marks can be seen along the edges, with a sharp deep fracture running through at the lower left part.

with distinctive flute marks and a brook flowing through underneath. The brook is the only water source encountered during the hike so be sure to get enough supply here.

Strangely enough, the boulder hosts a cave, a rare occurrence considering the rock itself is made of granite. The entrance may be small but the chamber inside is big enough for a person to stand straight.

Standing at more than 10 m high and 20 m wide, this boulder is a good spot for photography. The locals even set up a rope to climb above the rock, although cautionary measures must be taken for its slippery surfaces. Other boulders albeit smaller in size were found along the valley, with similar fluting marks. Apparently, the flute marks on rock surface is a common occurrence here.

Attractions along the hike

The main attraction to Bukit Baginda is the boulders phenomenon, and of course there are numerous of them along the way to the top. Therefore, be aware of your surrounding during the hike as the majestic phenomenon might be missed in thick jungle foliage.

Apart from the boulders, multiple flora can be observed along with a tree which the locals often harvest for *damar* (resin). However, improvements can be made to label the trees for educational purposes. Some stretch of route to the top may get very steep and slippery, so exercise caution during ascend and descend, and you may use the ropes provided.

The peak

450 meters above sea level, the peak of Bukit Baginda is a breathtaking small clearance with a banner signifying you made it to the top. No view of the surrounding scenery, really. So why did we go all the way here?

Main attraction isn't exactly at the peak. Just a small distance away is the "Wave Rock". Follow the signage and a huge boulder with distinctive flute marks (almost wave-like) that gives its name will be found just 2 minutes away.

Figure 3: Close up view of "fluting" structure of rock on the boulder. The occurrence in granite body is relatively rare in Malaysia, although documented in few isolated localities.

Figure 4: The "cave" underneath the boulder with a brook flowing through. You can observe the fluting marks on the roof which is rather intriguing. Tombs can also be found inside the opening, originating from a local lore.

Figure 5: Almost hidden along the path, this boulder exhibit flute marks almost deeper than the rest.

Figure 6: Root system of a tree rising above surrounding ground. The roots hold a massive boulder intact at the base.

Figure 7: A rather sad finding. An old tree trunk was cut down leaving the stump behind. The circumstances behind this was unclear but may be due to (illegal) logging practices.

Wave Rock

Perched near the peak of Bukit Baginda, this is where the Instagram worthy shots are. The wavy texture it's known for can only be found on one face of the rock, on its northwestern side. The flutes are well defined, each almost half a meter wide, stretching from top to bottom of boulder.

The flutes are parallel, with rounded inner space, apparently absent from any fractures. Some disputes the nickname "Wave Rock" since it is nowhere near similar to the famous wave rock formation in Australia. Nevertheless, this rocky feature does have its own uniqueness and deserve its recognition for the beauty.

The lore of Bukit Baginda

Remember the tomb found underneath the first boulder? It doesn't belong to anyone significant, not even to anybody either – it's just a replica. That's what the guide told us. But don't feel scammed because the tomb holds a story.

Figure 8: The banner at the top. It's the only thing that signifies the peak of Bukit Baginda. (Picture from http://mchiker.blogspot.com)

Figure 9: The "Wave Rock". Note the distinctive fluting marks running from the top to bottom of rock, almost parallel to each other. This rock face is almost 10 m high.

Figure 10: Close up view of the parallel flutes running through the rock face. The feature is influenced by any fracture system observed.

Figure 11: The size of the flute marks is almost similar to these surrounding tree trunks.

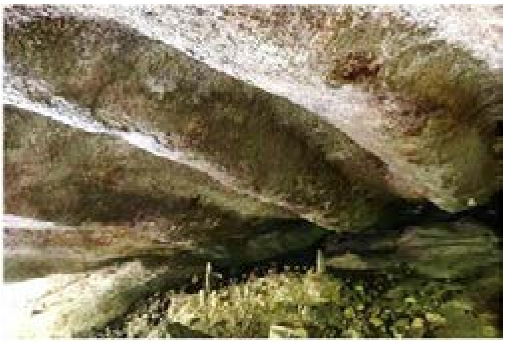

Figure 12: The tomb inside the cave underneath the rock at base of Bukit Baginda. Apparently, the tomb is unoccupied.

Figure 13: The lack of discontinuity inside rock mass is evident on site. Contrary to usual granite landforms, the flute markings are not structurally controlled.

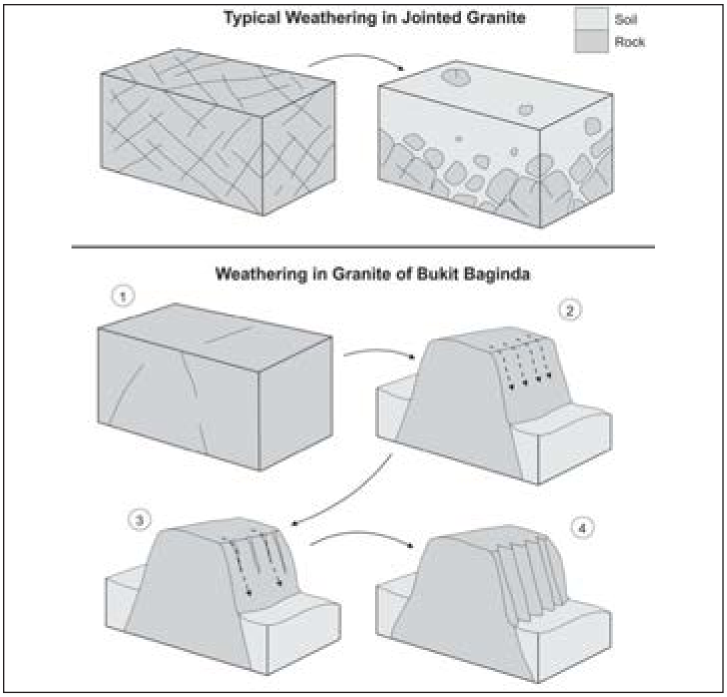

Figure 14: The process of flute formation along the vertical sides of a boulder. Compared with usual jointed granite that form thick soil layer in tropical countries, the lack of joint in Bukit Baginda's granite (1) explains the formation of huge boulders. Water flow (2) forms small channel on the side face (3) that expands into larger flute marks (4) over time. Flutes are almost vertical from the boulder position, any flute formation that was overturned or tilted may be explained with movement after the formation (eg: boulder fall).

The ascend to the top of Bukit Baginda symbolizes the start to life from childhood to be a full grown adult. The peak of Bukit Baginda itself signifies the peak of one's life, achieving long time goals with stable life. The descend of Bukit Baginda symbolizes the gradual decline with old age and eventually death, signified by the tomb inside the cave underneath the rock.

However, the name Bukit Baginda itself is yet to be ascertained of its origin. Even the guide and members of Museum Department (stumbled upon hiking) cannot give a concrete answer. Perhaps a mystery to be deciphered?

The geology behind Wave Rock

Flute landforms are a rare occurrence in granite province, especially in tropical climate whereas granite body often decomposed into residual soil. Site observation found a crucial feature in local granite body that explains the formation of flute morphology – the lack of discontinuities (fractures) in rock mass.

Geological structures including fault and fractures play an important role in shaping granite landforms. In tropical climate, chemical weathering attacks these structures, often resulting in intense weathering profile (Grade IV-V soil). The resulting profile often exhibits a very thick soil layer (often exceeding 20 m) with rounded core stones.

The case of Bukit Baginda is rather different, although site observation shows the rock is made of granite, major discontinuity sets are absent except few sheeting joints. This feature disallows weathering to penetrate deep into rock mass, instead leaving only the outer surface exposed to elements of weathering.

Repeated rainfalls mean water frequently flows along the edge of the rock. As it flows, the chemical and mechanical process eroded rock materials along its path. Over time, the water flow path eroded enough material to form a small flute that grows over time. Flute features can only be observed on vertical sides of a rock boulder. Boulder movements (overturning) may lead to flute features to be observed on cave roof in Figure 4 and 12.

Conclusion

Further studies need to be done to establish the mineralogy including its mechanical and chemical properties of the rock to concretely explain the formation of flute in granite body.

Apart from Bukit Baginda, flute marks on granite boulders were also observed in Tampin, Negeri Sembilan. Coastal granitic outcrops are among typical landforms that exhibit this feature, among them are Pulau Tioman (Pahang) and Pulau Ubin (Singapore).

Figure 15: Writer with team members at "Wave Rock" near the peak of Bukit Baginda.

This site has the potential to be a geosite – where visitors and tourists can learn about geology behind its formation. Those who are fascinated on geologically controlled landform will appreciate such rock morphology which rarely seen in tropical granite area. However, improvements need to be done on infrastructures particularly quality of hiking trail and surrounding public amenities.

Reference

http://mchiker.blogspot.com/2018/10/bukit-baginda-batu-kikir-negeri-sembilan.html

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UPCOMING EVENTS*

February 21-24, 2021: Energy in Data Conference; Austin, Texas. More details can be obtained at https://energyindata.org/.

March 9-10, 2021: 4th AAPG Geothermal Cross-over Workshop, Utrecht, The Netherlands. Contact the Events and Office Administrator at (+44 (0) 203 962 4468) for further details.

March 17-18, 2021: AAPG Geosciences Technology Workshop (Virtual Workshop via Zoom).

March 23-25, 2021: 13th International Petroleum Technology Conference (IPTC); Kuala Lumpur, Malaysia. For queries, email: iptc@iptcnet.org.

April 5-7, 2021: Exploration and Development of High Pressure and High Temperature Reservoirs, Kuwait City, Kuwait. Visit https://www.aapg.org/global/middleeast/events to obtain more details about the event.

April 5-9, 2021: National Geoscience Conference, Bangi, Selangor, Malaysia. To find out more, send email to: conferencengc2020@gmail.com, or visit website, http://www.geologys.online.

May 3-6, 2021: Offshore Technology Conference, Houston, Texas, USA. Visit website: http://2020.otcnet.org/ for further details.

May 4-6, 2021: 5th Myanmar Oil & Gas Conference; Yangon, Myanmar. More information can be obtained at https://eage.eventsair.com/fifth-aapg-eage-myanmar-conference/.

May 23-26, 2021: ACE 2021, Denver, Colorado. Visit event website at https://ace.aapg.org/2021 for further details.

May 25-26, 2021: Conference on Mixed/Hybrid Systems (Turbidite, MTDs and Contourites) on Continental Margins, Lisbon, Portugal. For details, contact the Events and Office Administrator at +44 (0) 203 962 4468.

July 26-68, 2021: Unconventional Resources Technology Conference (URTeC 2021), Houston, Texas. For further information, please visit: https://urtec.org/2021.

August 11-12, 2021: AAPG/EAGE Geosciences Technology Workshop - High CO_2, High Contaminant Challenging Fields, and Alternative Energy, Ipoh, Perak, Malaysia. For details, please contact: Adrienne Pereira, AAPG Asia Pacific: apereira@aapg.org; Gerard Wieggerink, EAGE Asia Pacific: gw@eage.org.

September 27-29, 2021: Integrated Process-Based Geological Modeling in Exploration and Production, Abu Dhabi, United Arab Emirates. Visit https://www.aapg.org/global/middleeast/events to obtain more details about the event.

October 4-7, 2021: 14th Middle East Geosciences Conference and Exhibition; Bahrain. To find out more, visit website https://geo-expo.com/conference/, or contact Mr. Abeer Al Zubaidi at email: aapgme@aapg.org.

October 24-27, 2021: AAPG 2021 International Conference & Exhibition (ICE); Muscat, Oman. Further details will be made available, visit https://www.aapg.org/events/conferences/ice.

* Subject to re-evaluation by the organizers due to the unprecedented disruptions brought about by the COVID-19 pandemic.

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Manuscript

The paper can be written in Bahasa Malaysia (Malay) or English. For English papers, use either British or American spelling but not a combination of both. The paper should be checked thoroughly for spelling and grammar. The manuscript must be printed at 1.5 spacing in a single column on one side of A4 paper. All pages should be numbered. Length of paper should be between 3,000 and 6,000 words for the Bulletin and between 2,000 and 3000 words for Warta Geologi, excluding tables and illustrations. Metric units should be used and all non-standard symbols, abbreviations and acronyms must be defined.

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Title must be informative and reflects the content of the paper. Title in Malay should include an English translation. It should be concise (less than 20 words). Avoid using abbreviation in the title.

Author's Address

Addresses of all authors must be provided. The addresses should be sufficient for correspondence. Please include email address, telephone and fax of the corresponding author.

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Abstract should not exceed 300 words. Articles written in Malay language should also be accompanied by English language abstracts and keywords.

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Please include 3 to 8 keywords that best describe the content of the paper.

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In the text, references should be cited by author and year and listed chronologically (e.g. Smith, 1964; Jones et al., 1998; Smith & Tan, 2000). For both Malay and English paper, all references must be listed in English. Title of non-English articles should be translated to English.

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Book:

Hutchison, C.S., 1989. Geological Evolution of South-east Asia. Clarendon Press, Oxford. 368 p.

Chapter of book and Symposium volume:

Hosking, K.F.G., 1973. Primary mineral deposits. In: Gobbett, D.J. and Hutchison, C.S. (Eds.), Geology of the Malay Peninsular (West Malaysia and Singapore). Wiley-Interscience, New York, 335-390.

Article in Malay:

Lim, C.H. & Mohd. Shafeea Leman, 1994. The occurrence of Lambir Formation in Ulu Bok Syncline, North Sarawak. Geol. Soc. Malaysia Bull., 35, 1-5. (in Malay with English abstract)

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