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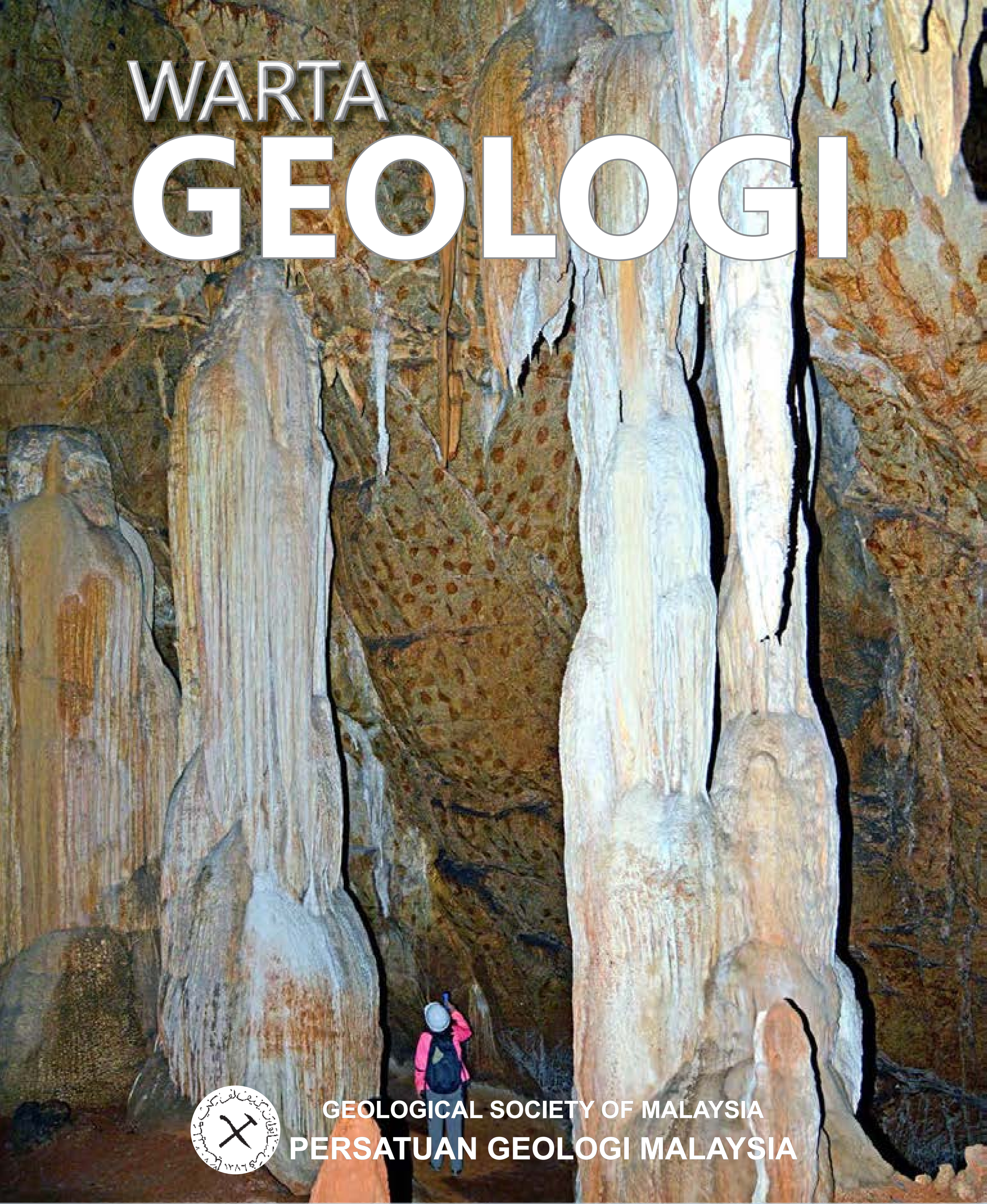

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Cover photo: Batik cave chamber of the Fig Tree Cave at northern Batu Caves limestone hill. The chamber gets its name from the spotted markings on the roof and wall, probably caused by roosting bats. Photo by T. F. Ng

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The shaping and demise of the Tusan Beach "Drinking Horse", southwest of Miri, Sarawak

Franz L. Kessler[1,*], John Jong[2]

[1] Goldbach Geoconsultants O&G and Lithium Exploration, Germany
[2] JX Nippon Oil and Gas Exploration (Malaysia) Limited, Malaysia
* Corresponding author email address: franzlkessler32@gmail.com

Abstract: The Miri-Bekenu coastline is formed by Neogene clastic rock formations that are poorly consolidated. These formation outcrops are shaped by weathering elements of tropical rainfall, wind and coastal erosion, and deformation processes such as tectonic uplift, structural faulting and folding. The geological monuments of the Miri area such as the iconic Tusan Beach "Drinking Horse" cliff structure generally withstand weathering degradation and coastal erosion poorly. Further to this, housing projects, road constructions and encroaching new plantations had their share in destructing geological landmarks. In this article, we discuss the case study of the "Drinking Horse" starting from its creation, the impact of weathering elements and coastal erosion, plus human interferences that resulted in its ultimate demise. Nonetheless, due to its seaward-dipping sedimentary layers (including thin clay-rich beds), it was predestined for gravity sliding. Coupled with pounding erosion, the cliff inevitably collapsed and any prior preservation effort carried out to protect the structure would have been in vain.

Keywords: "Drinking Horse", Bekenu, Miri, Pantai Bungai, Tusan Beach

INTRODUCTION

The Tusan Beach (coordinates: 04007'32.1" N, 113049'25.9" E) with rocky cliff facing the South China Sea is located in the district of Bekenu, some 40 km SW of Miri accessible via the Coastal Road towards Bekenu (Figure 1). The beach is a popular geotourism site (Andriansyah *et al*., 2016; Kessler & Jong, 2018), as well as for petroleum geology related excursion with excellent exposure of massive sandstone layers often used as analogue for the subsurface petroleum reservoirs (Wannier *et al*., 2011; Kessler & Jong, 2018). On Thursday night, 20th February 2020, the iconic Tusan Beach "Drinking Horse", also famously known as "Horse Head Drinking Water" (Dayak Daily, 2020), a locally well-known tourist hotspot and cherished landmark (Figure 2), unexpectedly collapsed. There is nothing left of the famous sight except for a pile of rubble. In this article, we investigate the factors for the shaping of "Drinking Horse", and discuss the impact of weathering elements and marine coastal erosion that ultimately resulted in its demise.

LOCAL STRUCTURAL SETTING

The prominent "Drinking Horse" cliff structure, formed by Neogene massive channelized sandstone and claystone sedimentary layers, was sculptured by the onslaught of tropical rainfalls, wave and wind erosions, as well as by longshore currents. The cliff section between Miri and Bekenu (Figure 1) has shown itself being particularly vulnerable to erosion for the following reason:

- The formation consists of a sequence of Neogene and poorly consolidated rocks, it dips with a relatively gentle angle of 10° (South of Miri) to a steep vertical 90° (North of Bekenu) facing the South China Sea, with the effect that longshore currents incise the coast layer-by-layer into the rock formation (Figures 3 and 4). Near the Tusan cliff section, including the "Drinking Horse" structure, the seaward dip angle is in the order of 35°; with the strike/dip of the sedimentary layers as measured by Andriansyah *et al.* (2016) reportedly N225°E/35°. Pounded by coastal currents, waves and affected by bio-erosions (Dodge-Wan & Nagarajan, 2019; 2020), as well as scoured by wind and rainfall, the cliff section became unstable. Finally, gravity sliding (thin layers of mudstone between the massive sandstone are also facilitating land-sliding) led to its ultimate collapse. Interestingly, it was reported in the local press that "Building of access road could have hastened Horse's demise" (Borneo Post, 2020), hence human interferences may have had a detrimental impact to the destruction of the cliff section.
- Furthermore, the cliffs are weakened by the effects of structural folding and faulting, with tectonic pulses affecting the area until the Holocene (Kessler & Jong,

Figure 1: Aerial photograph showing the position of the “Drinking Horse” evolved from “Headland 2” on the actively eroding coastline between Miri and Bekenu. Index maps show the location of Tusan and Tanjung Batu beach areas. The seismic section shown in Figure 9 is located offshore of Pantai Bungai.

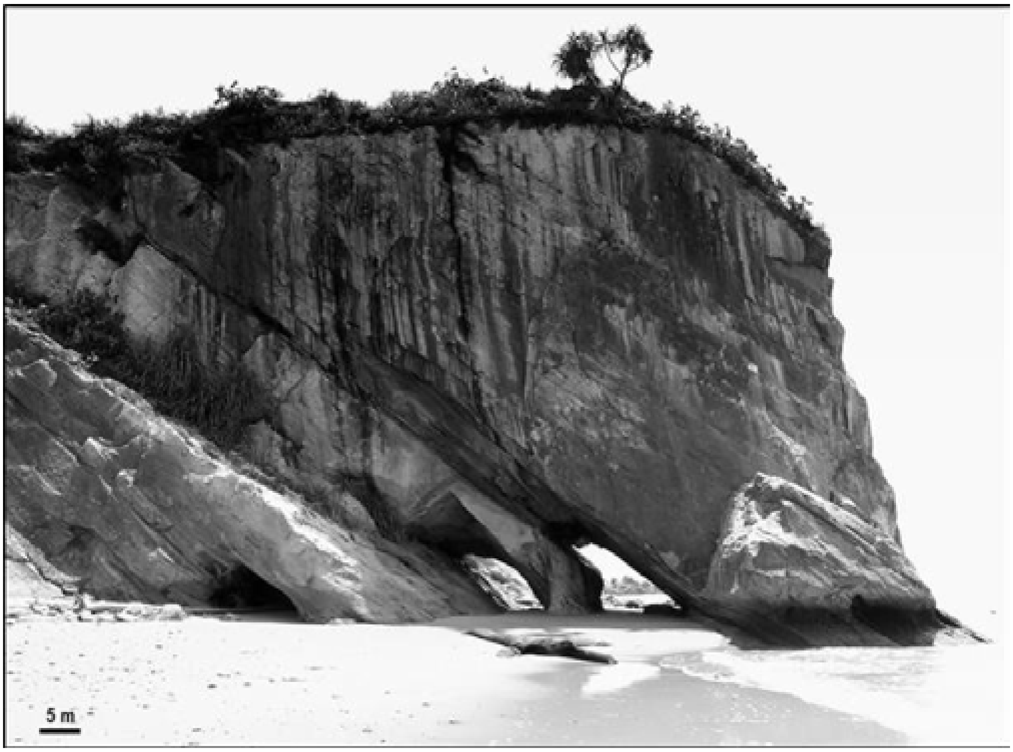

Figure 2: Photo of the “Drinking Horse” taken around 2012. At this time it looked rather like a water-drinking boar. The rock section is formed by 35° N dipping clastics, with a prominent body of mid-size, cross-bedded sandstones with minor interbedded claystones. The roof of the horse is capped by a marine abrasion terrace that originated at the end of the Pleistocene (see Figure 7). Note the bottom part (mouth piece) of the area was affected not only by wave action, coastal current incision, but was also prone to biological weathering by isopod *Sphaeroma triste* (Dodge-Wan & Nagarajan, 2020).

Figure 3: Longshore current and wave actions have eroded the bottom section of the rock face causing the collapse of the overlying section.

Figure 4: The seaward-dipping clay sections form ideal gliding surfaces, and particularly after strong rainfalls the rock face becomes unstable and collapses.

2014a & b; 2015a & b; 2017). The geological map in Figure 5 and the profile sections shown in Figure 6 indicate the amount of tectonism in this rather young and active basin. In the profile of Figure 7, we see the coastal section as being the northern leg of a tectonic zone characterized by strike-slip faulting and thrusting.

- Observing the cliff section over a period of some 12 years, one recognizes how fast the coast is being eroded, in the order of 2 m/year. Looking towards the sea, one notices a shallow greenish shallow-water zone which reaches more than a kilometre out into the sea and indicates a zone of previous

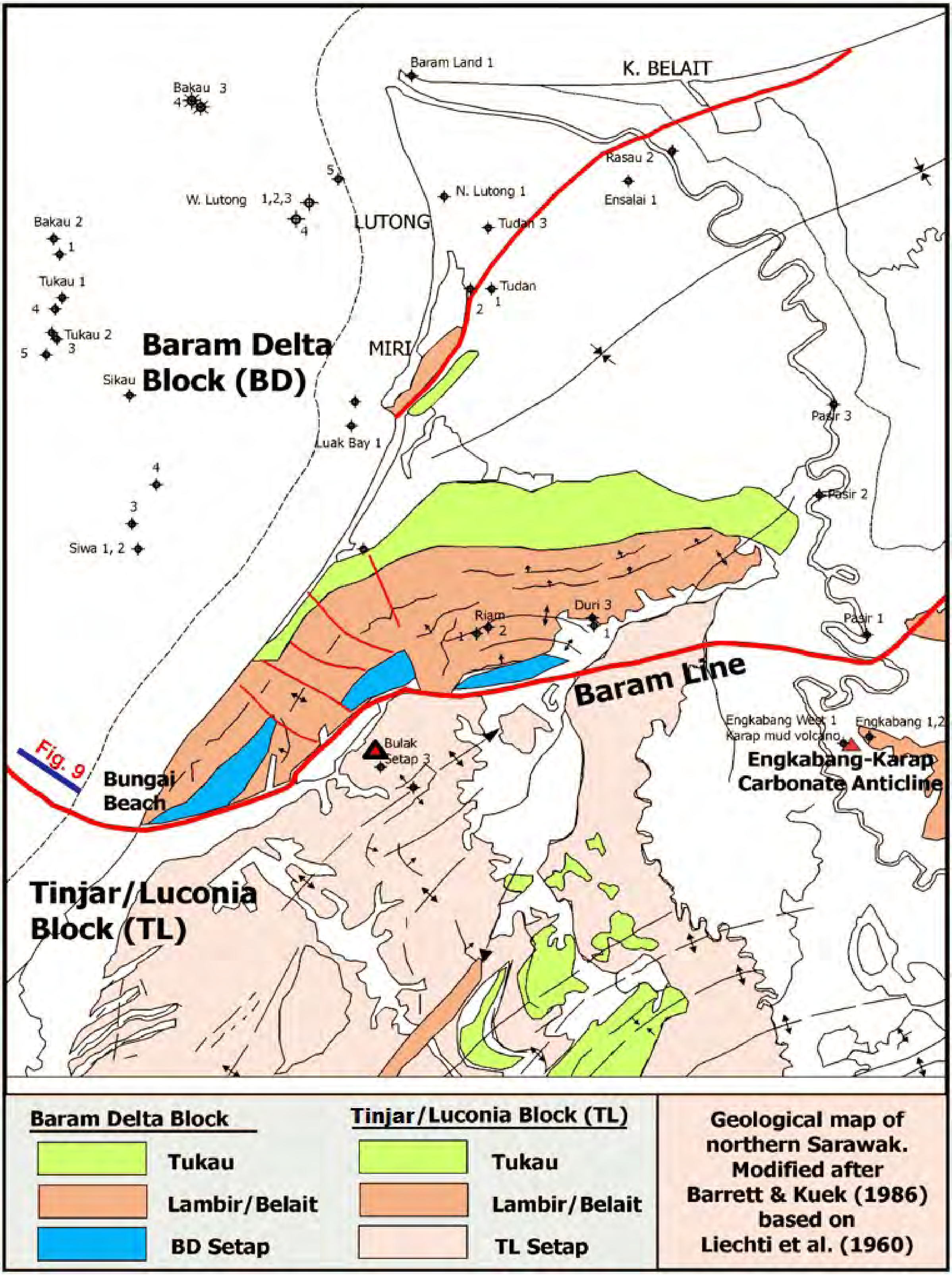

Figure 5: Simplified and updated geological map of northern Sarawak with active thrusting and folding (from Jong & Kessler (2019), modified after Barrett & Kuek (1986) based on Liechti *et al*. (1960)).

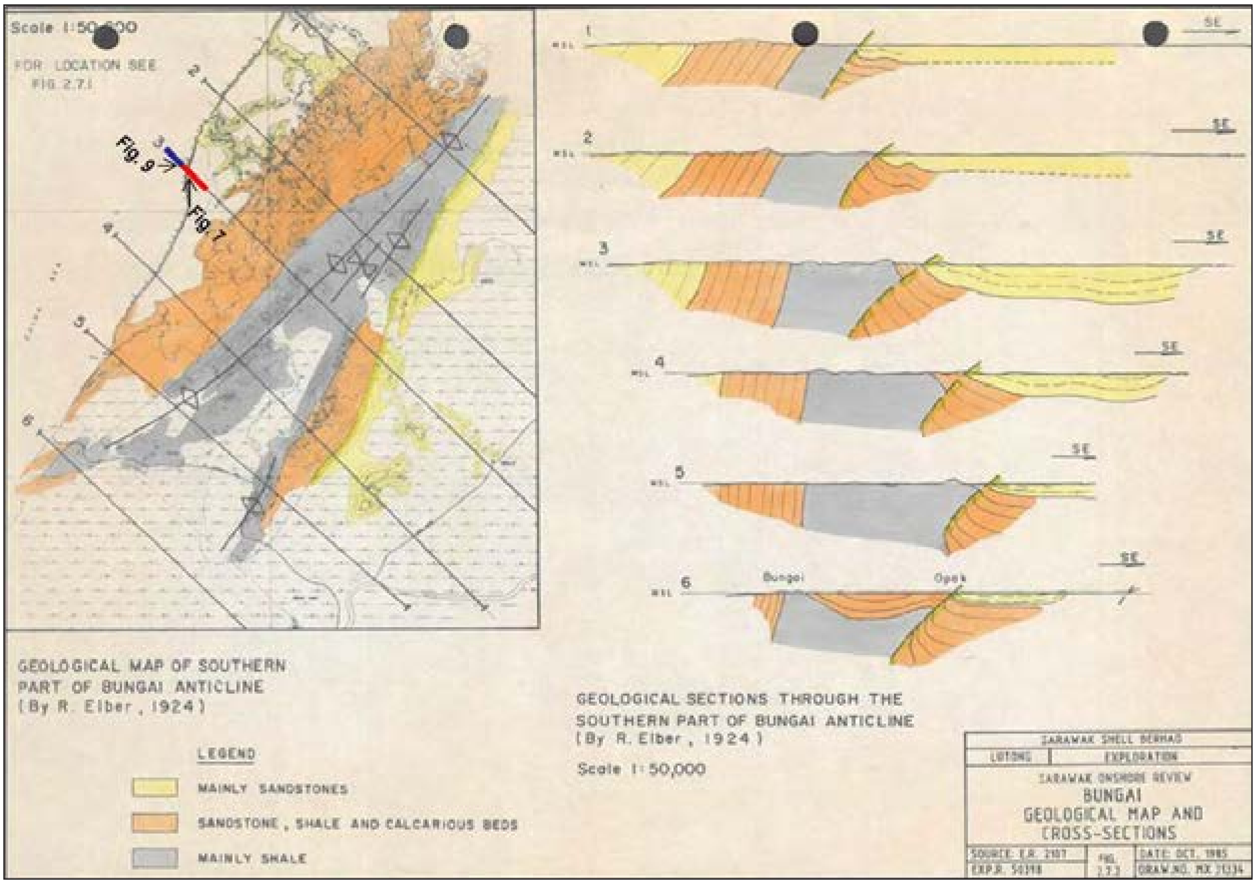

Figure 6: Re-drafted geological sections by Shell of older geological field sections. The "Drinking Horse" lies at the NW end of Profile No. 3 with approximate locations of Figures 7 and 9 indicated (from Barrett & Kuek, 1986).

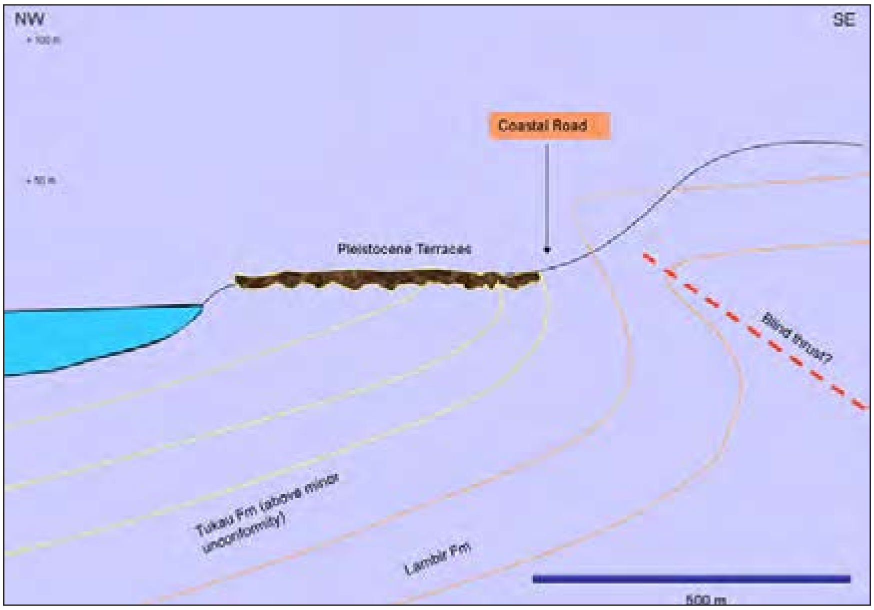

Figure 7: Tectonic profile section in the vicinity of the Tusan cliff area, which shows seaward dipping of the formation underlying the Pleistocene terraces. Note the approximate location of profile section is at the NW end of Profile No. 3 in Figure 6.

abrasion by wave action (Figure 8). Furthermore, on an old seismic line (Figure 9, Line 1141 acquired in the early 60's), we can see abrasion/erosion on the eastern end, and deposition (as onlap) in the NNW.

- The coastline is also characterized by pulses of uplift and the formation of abrasion terraces. The most prominent terrace was formed in the latest Pleistocene, and has been uplifted in the Tusan area by some 20 meters (Kessler & Jong, 2014a). Minor terraces are indicative for an uplift that may even continue to present day (Figure 10).

In summary, we observe a combination of tectonic forces and (the by far more important) combined erosional processes which shaped and continue to shape the morphology of the coastline.

Figure 8: Looking towards the sea from the Tusan cliff area, one notices a shallow greenish shallow-water zone which reaches more than a kilometre out into the sea indicating a zone of previous abrasion and erosion by wave action.

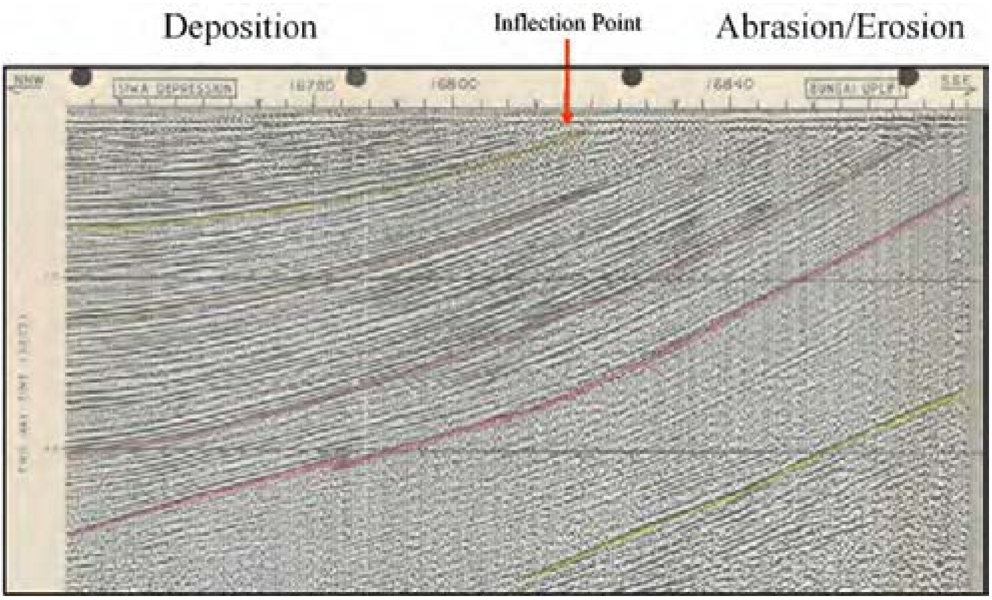

Figure 9: On an old seismic line (Line 114, acquired in the early 60's), we can see abrasion/erosion on the eastern end (Pantai Bungai), and deposition in the NNW basinal area. The abrasion platform of Figure 7 corresponds to the area of truncated seismic event. Note the approximate location of the section at the NW end of Profile No. 3 in Figure 6 (from Barrett & Kuek, 1986).

SHAPING THE "DRINKING HORSE" AND ITS DEMISE

In 2009 (Figure 11), the "Drinking Horse" as we knew it later, did not exist. The so-called "Headland 2" (Figure 1), stood out as a square block mainly formed by sequences of channelized sandstone with interbedded claystone layers. Waves and currents had already carved out a rock pillar, which collapsed around 2010.

Around the same time, longshore currents started to scour the promontory (Figure 12), and created caves which grew in size over time (Figure 13). By 2012, as the erosion processes continued, the caves became bigger and roof sections within the caves collapsed (Figure 13). In addition, the effect of bio-erosion, which is occurring in the Tusan beach area, is also mentioned by Dodge-Wan & Nagarajan (2019 & 2020).

Over the years, more roof section collapsed, and the previous two separate caves had coalesced to form one large cavity (Figure 14). In the picture taken in 2017 (Figure 15), we understand how fragile this geological landmark had become. Then, in early 2020, the inevitable happened - the "Drinking Horse" collapsed overnight on 20th February, perhaps also triggered by road construction to the cliff area (Borneo Post, 2020; Dayak Daily, 2020; Figure 16). Sadly, the lifespan of the "Drinking Horse" was a mere 11 years since its creation in 2009.

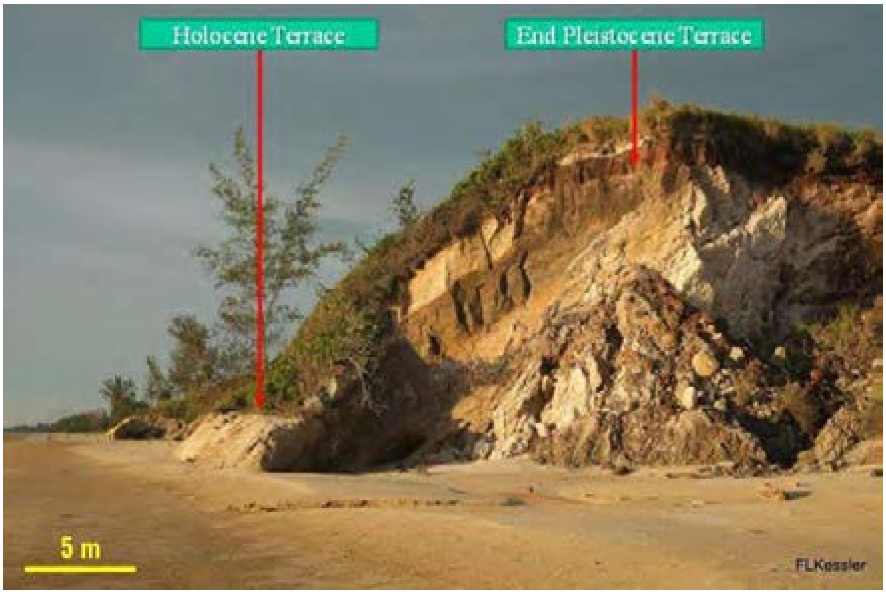

Figure 10: The most prominent terrace formed in the latest Pleistocene, and has been uplifted in the Tusan area by some 20 meters (Kessler & Jong, 2014a). Minor terraces are indicative for uplift pulses that may even continue to present day.

Figure 11: In 2009, the "Drinking Horse" as we knew it later, did not exist. The so-called "Headland 2" stood out as a square block mainly formed by sequences of channelized sandstone layers. Waves and currents had already carved out a rock pillar to the right, which collapsed ca. 2010.

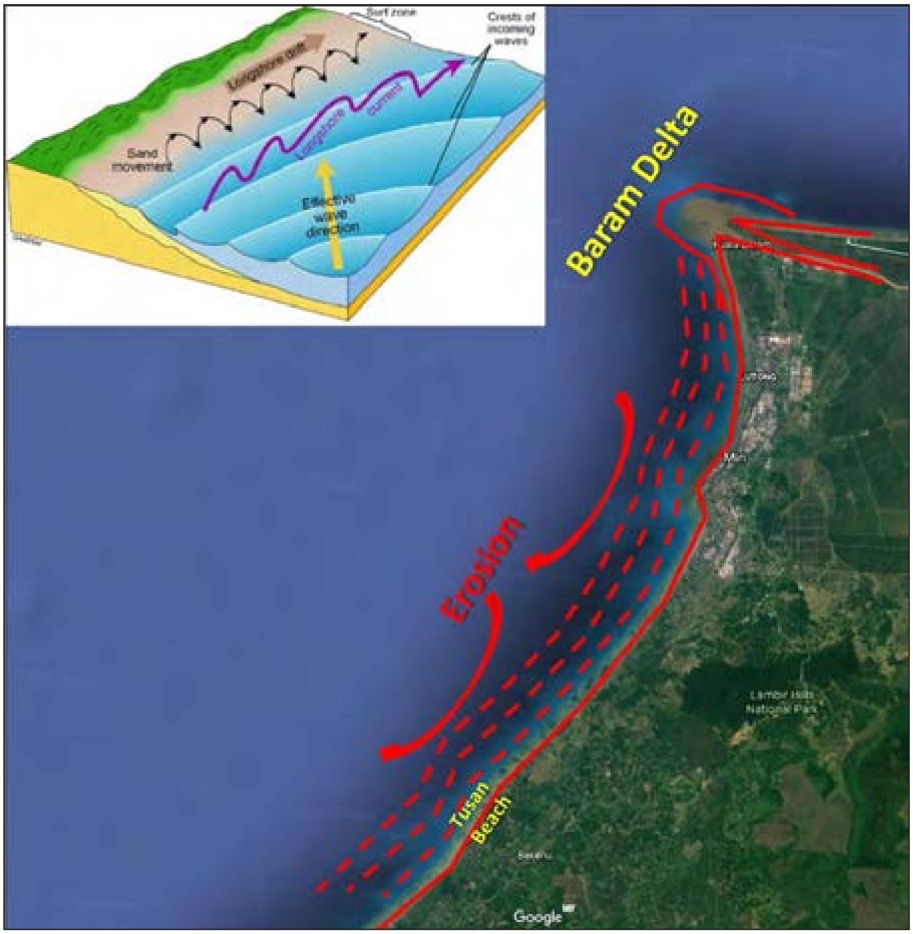

Figure 12: The mechanism of longshore currents resulted in severe coastal erosion along the Miri-Bekenu coastline.

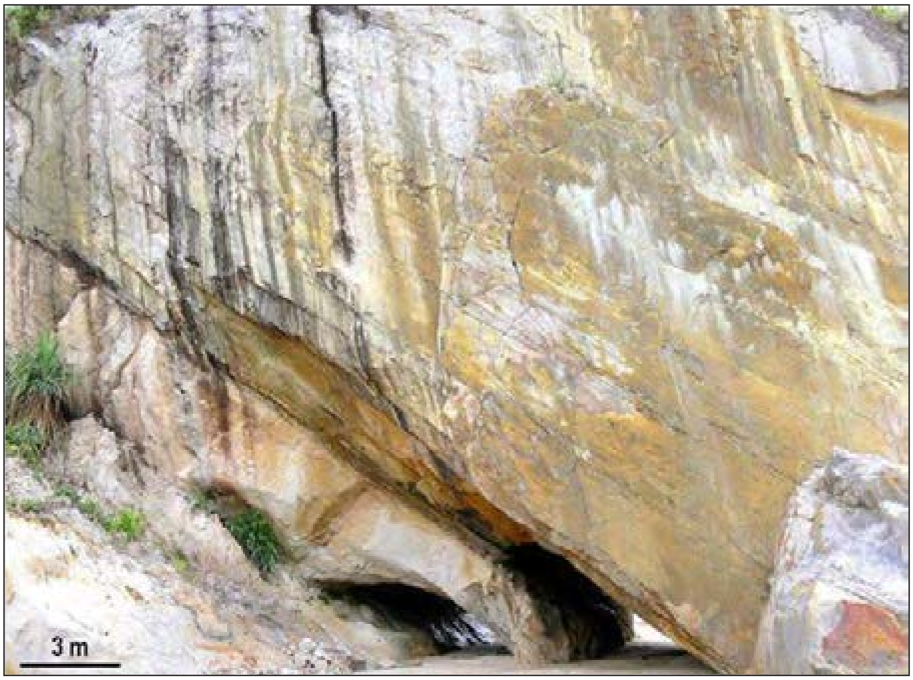

Figure 13: In 2010, longshore currents and bio-erosion started to scour the promontory, and created caves which grew in size over time.

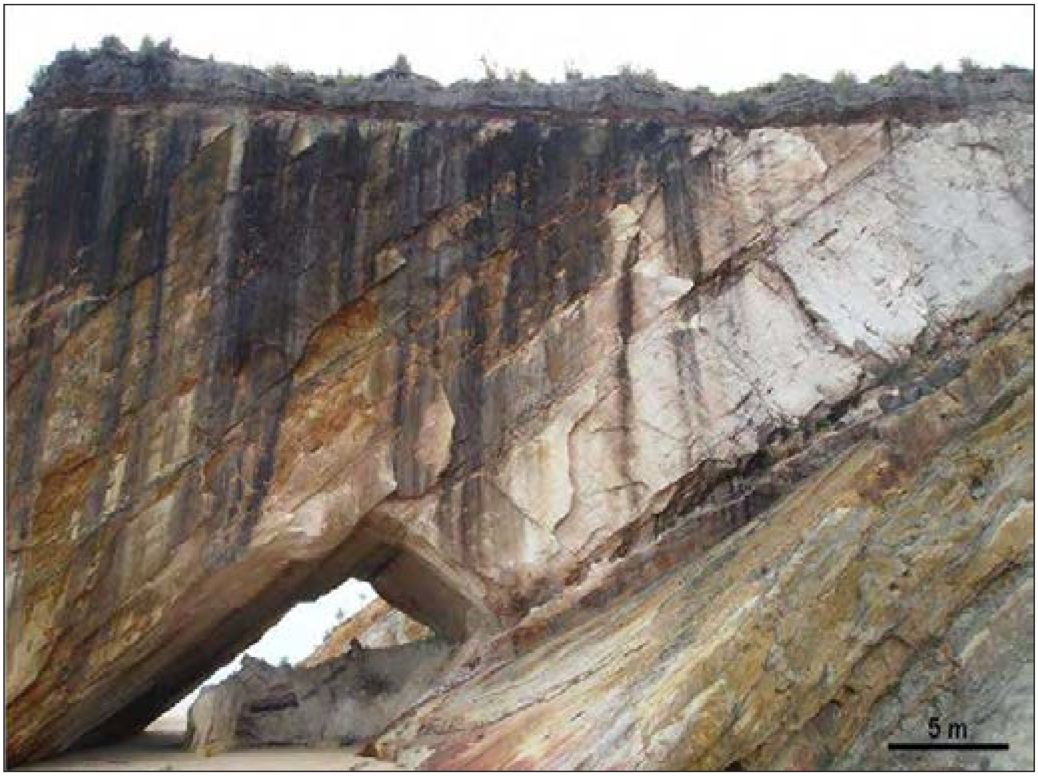

Figure 14: As the coastal and bio-erosion processes continued, the caves became bigger and roof section within collapsed.

Figure 15: Over the years, more roof section collapsed, and the previous two caves had coalesced to form one large cavity. In this picture taken around 2017, we understand how fragile this geological landmark had become (photo credit: Curtin University Malaysia).

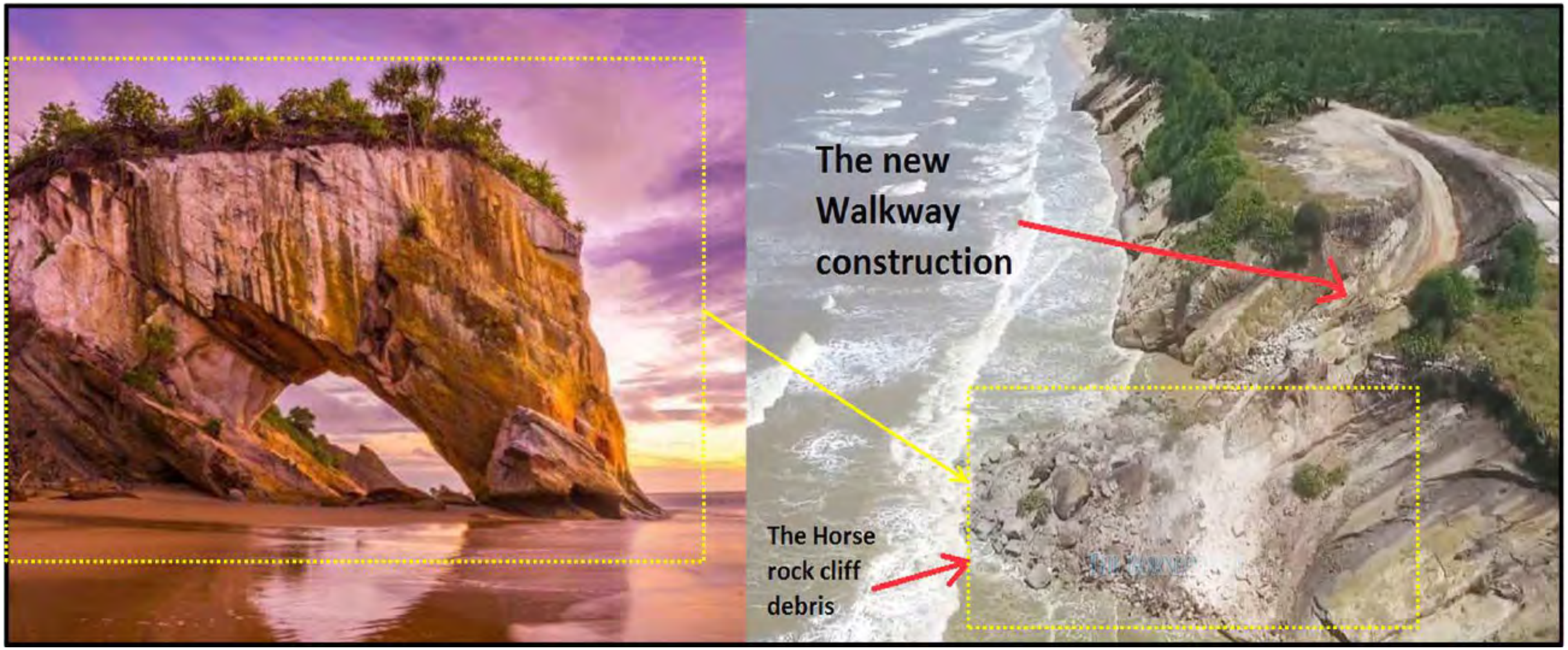

Figure 16: In 2020, the inevitable happened - the “Drinking Horse” collapsed, perhaps triggered by development measures and road construction (photo credit: Left, Curtin University Malaysia; Right, Borneo Post).

DISCUSSION

Could the "Drinking Horse" be saved? Despite the fact that geotourism has benefitted Miri, and likewise local kampung economics to some extent, the area geotourism potential was not recognized for many years. This seems to have changed a while ago, but development plans and actions to save and preserve geological features such as the iconic "Drinking Horse" have come a bit late. As the years passed, one after another geological monuments fell down, or were bulldozed for the sake of housing development and road construction projects, or gave way to new plantations.

Apart from the "Drinking Horse", one good example for this was the destruction of a world-class outcrop in Sungai Rait, which is now inaccessible due to the construction of a chicken farm (Figure 17), in addition to falling prey to degradation by weathering and vegetation. If on same occasions we believe that the geological monuments of the Miri area could have been saved such as the famous Airport Road Outcrop (Wannier *et al*., 2011; Kessler & Jong, 2018), in others such as the "Drinking Horse" it would have been nearly impossible to preserve it. Only the placement of large boulders in a demi-circle could have prevented waves and longshore currents from scouring the monument, however there are no access roads to bring the necessary amount of rock.

As remarked by Kessler & Jong (2018), until today there is little consciousness and conservation effort in respect to the potential touristic values of these geological monuments. Their preservation would require a masterplan spearheaded by the Miri City Council, in collaboration and with the support of the State government and Tourism Board to promote their geotourism potential, in addition to sustainable sponsorship of the local private industries to maintain these geological monuments.

CONCLUSIONS

The morphology of the Miri-Bekenu coastline is formed by Neogene clastic rock formations that are poorly consolidated. These are shaped by coastal and bio-erosions, rainfalls and wind actions, and deformation processes such as tectonic uplift, structural faulting and folding. Geological monuments of the Miri area are prone to rapid erosion. Further to this, housing and encroaching plantation projects had their share in destructing geological landmarks. The call for their preservation is imminent, and would require thoughtful considerations by the Miri City Council to promote their geotourism potential, and with sustainable sponsorship of the local private industries to maintain

Figure 17: The world-class rock escarpment suitable for petroleum geology-related excursion at Sungai Rait (see Kessler & Jong, 2018) has given way to a chicken farm and degraded by weathering and dense vegetation.

these geological monuments. However, in the case of the "Drinking Horse", any effort of protecting was proven to be in vain.

ACKNOWLEDGEMENTS

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The characteristics and morphology of columnar dacite in Tawau, Sabah

Elvaene James[1,2,*], Hennie Fitria W. Soehady Erfen[3], Azman A. Ghani[2], Angela Vidda Chuwat[4], Gerald Eko Ejiga[2]

[1] Dept. of Geoscience, Faculty of Earth Science, University Malaysia Kelantan, 17600 Jeli, Kelantan, Malaysia
[2] Department of Geology, Faculty of Science, University of Malaya, 50603 Kuala Lumpur, Malaysia
[3] Faculty of Science & Natural Resources, University Malaysia Sabah, 88400 Kota Kinabalu, Sabah, Malaysia
[4] School of Physics, University Sains Malaysia, 11800 Penang, Malaysia
* Corresponding author, e-mail: Elvaene_anne@yahoo.com

Abstract: The occurrence of columnar jointing is commonly associated with volcanic rocks and a rapid cooling environment. We recently discovered well-preserved columnar dacite on the road cutting slope in the eastern part of Tawau town, Sabah. This paper briefly describes the occurrences and morphology of columnar dacite in the study area. Columnar dacite exhibits entablature feature since it has thinner and chaotic columns. The hexagon side dominates the columnar joints with minor pentagons to heptagon sides. Columns for dacite are much smaller compared with columnar basalt Tawau. The formation of columnar joints was influenced mainly by external fluid where the water flow on top of the cooling lavas makes it cool rapidly.

Keywords: columnar dacite, entablature, Tawau, rapid cooling

Abstrak: Kejadian kekar turus biasanya berasosiasi dengan batuan volkanik dan persekitaran yang cepat menyejuk. Penemuan terbaru dasit turus yang terpelihara secara baik telah dijumpai pada cerun pemotongan jalan raya yang terletak di bahagian timur bandar Tawau, Sabah. Kajian ini menjelaskan serba sedikit berkaitan dengan kejadian dan morfologi dasit turus di kawasan kajian. Dasit turus menunjukkan ciri-ciri '*entablature*' memandangkan ianya mempunyai turus yang lebih nipis dan tidak teratur. Kekar turus lebih didominasi oleh sisi hexagon selain turut menunjukkan sisi pentagon ke heptagon. Turus untuk dasit adalah lebih kecil jika dibandingkan dengan turus basalt di kawasan Tawau. Formasi kekar turus lebih banyak dipengaruhi oleh cecair luaran memandangkan air yang mengalir pada bahagian atas lava yang sedang menyejuk boleh mengakibatkan penyejukkan cepat.

Kata kunci: dasit turus, entablature, Tawau, penyejukan cepat

INTRODUCTION

The occurrences of columnar basalt in Tawau, Sabah is considered as a fascinating and spectacular scenery that attracted many tourists to visit this area. Columnar jointing is not usual; however, it does occur around the world with different rock types. In East Malaysia, columnar basalt are exposed in few locations such as Tawau, Tatau and Kapit (Lim, 1988; Nur Iskandar, 2006; Sanudin *et al*., 2010; Moul & Noweg, 2018). Unlike columnar basalt in Tawau, the exposure of columnar jointing in Sarawak is not vast. Around the world, only a few places report the exposures of columnar jointing that consists of felsic volcanic rocks such as St. Mary's Island, India (columnar rhyolite; Melluso *et al*., 2009), Atsumi Japan (columnar dacite; Goto & Tsuchiya, 2004) and Papuk Geopark, Croatia (columnar rhyolite; Balen & Petrinec, 2014). Usually, columnar jointing is associated with igneous bodies, which can be divided into columns and a network of polygonal fractures (Hetényi *et al*., 2012). The fractures are formed during the cooling-induced contraction of lava which leads to hydrothermal fluid circulation (Lamur *et al*., 2018). Recently we discovered an outcrop of columnar dacite on the road cutting near the Tawau town area. The columnar dacite has different morphology compared to columnar basalt in Tawau. This paper will briefly describe the occurrences and morphology of columnar dacite.

GEOLOGICAL SETTING

Sabah is located in the northern part of Borneo and is considered part of the Eurasian Plate or Sundaland Block (McCaffrey, 1996; Simon *et al*., 1999; Hall, 2012). Sabah basement rocks consists of the Mesozoic crystalline basement (Hutchison, 1988) and overlain by a Cenozoic sedimentary rock (Hall, 2013). In the Early Miocene, a collision between northern Borneo and the South China continental margin led to Sabah orogeny and ceased the subduction of the Proto-South China Sea (Rangin *et al*., 1990; Hall, 1996; Hutchison, 1996; Hall & Wilson, 2000; Hutchison *et al*., 2000). During the Late Miocene, plutonic magmatism started to intrude into the Crocker Formation to form Mount Kinabalu (Cottam *et al*., 2010; Hall, 2012) due to extensional thinning of the crust during the Early Neogene (Hall, 2013). Cottam *et al*. (2010) suggested that the forming of plutonic intrusion during the Late Miocene is not related to subduction.

The occurrences of volcanic rocks are mainly focusing on the eastern part of Sabah. Semporna Peninsula is divided into Mesozoic oceanic crust, the Middle Miocene volcanic arc, and Plio-Pleistocene volcanic arc (Sanudin *et al*., 1995; Hutchison, 2007). Volcanic rocks in Semporna and Dent Peninsulas are related to the northward subduction of the Celebes Sea (Hall & Breitfeld, 2017). The formation of the Sulu Arc was related to the subduction of the Proto-South China Sea (Rangin & Silver, 1990). The Sulu Arc can be traced onshore on Semporna and Dent Peninsula (Chiang, 2002) and extended westward of the Semporna Peninsula towards the Zamboanga Peninsula (Garwin *et al*., 2005). Southeast Sulu Sea volcanic rocks characterized by N-MORB/island arc tholeiite (IAT) transitional features, and island arc tholeiitic (Spadea *et al*., 1991, 1996). However, calc-alkaline lavas features are dominant in the north Sulu Sea (Spadea *et al*., 1991, 1996). Neogene volcanism occurs across Tawau, Kunak, and Semporna on the Semporna Peninsula (James *et al*., 2019). Macpherson *et al*. (2010) explained mantle resembling Ocean Island Basalt (OIB) might occur in the Semporna Peninsula, throughout the Sulu Arc and the South China Sea. However, the subduction-related signature is more dominant in Semporna Peninsula volcanic rocks (James *et al*., 2019). Volcanic rock at other places such as Kunak shows features of MORB (James *et al*., 2019). Trace elements geochemical on subduction related volcanic rocks from Semporna shows mixture tectonic significance of island arc and plate margin basalt, while OIB-like and MORB volcanic rocks fall under continental setting (James *et al*., 2019). The study area is located in Tawau, southeast of northern Borneo (Figure 1A). In the Tawau area, most eruptions occurred through cinder cones (Macpherson *et al*., 2010). Olivine basalt at Taman Bukit Tawau, Tawau, is considered the youngest phase of magmatism, which shows the age of Pleistocene based on Thermoluminescence age dating (Takashima *et al*., 2005) and zircon U-Pb dating (Yi-Ju, 2018). The occurrence of olivine basalt may be formed as a monogenetic volcano as it came up from a deep-seated magma reservoir (Takashima *et al*., 2005). Zircon U-Pb

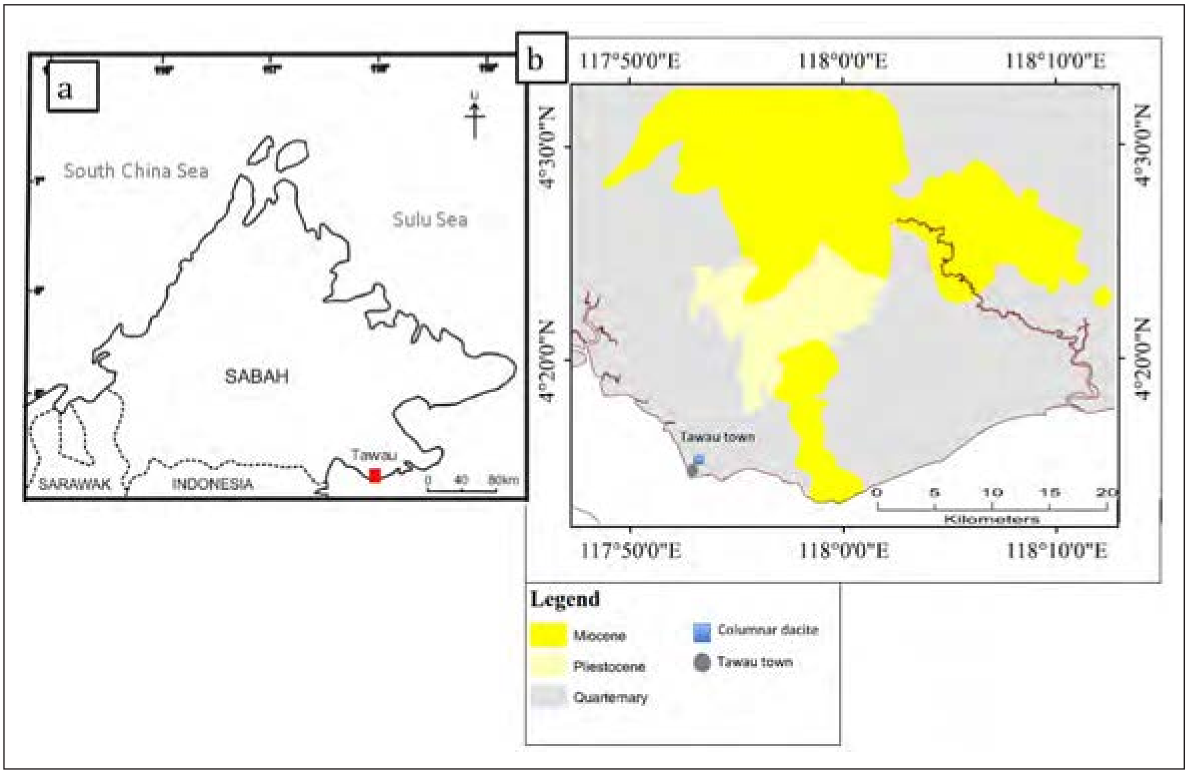

Figure 1: (A) Satellite image of Tawau located in southeastern of Sabah, East Malaysia. Figure taken from Google map. (B) Locations of columnar joints in Tawau, Northern Borneo.

dating shows that the age of columnar dacite is around 9.26 ± 0.26 Ma and indicates magmatic origin (James & Ghani, 2019).

OCCURRENCES, MORPHOLOGY, FORMATION AND FACIES OF COLUMNAR JOINTS

The outcrop of columnar dacite is exposed at the roadside near the Tawau town area (coordinate: 4°17.873' N, 117°56.727' E) (Figure 1B). The outcrop is covered with vegetation and palm plantation (Figure 2a and overlain by dacitic lavas flow (Figure 2b). The height of the outcrop is around 6 meters, and the width is not more than 20 meters. Columnar joints have two jointing facies which consist of a colonnade with regular columns and near-planar sides and entablature, which have more thinner, less regular columns with a curving side (Spry, 1962; Daniels *et al.*, 2013) and chaotic columns to flow top (Figure 2c). Columnar dacite in the study area shows entablature signatures with thinner and curving columns (James & Ghani, 2018). Columnar jointing dacite is dominated by hexagon shape, with minor occurrences of pentagons to heptagon shape, which also similar to columnar basalt Tawau (Sanudin *et al.*, 2010). The formation of columnar joints is mainly influenced by external fluid which results in highly rapid cooling due to the water flow on top of the lava. Lamur *et al.* (2018) demonstrate that columnar jointing forms well in a solid-state volcanic rocks and further promotes advective cooling in magmatic-hydrothermal environments. Furthermore, a combination of large-scale constitutional supercooling and thermal contraction processes may play essential roles in developing the columnar jointing (Balen & Petrinec, 2014).

PETROGRAPHY

The colour of the dacite is light greyish and slightly weathered on the outer layer surface (Figure 3). Dacite shows fine-grained, aphanitic, and porphyritic textures (Figure 4a). The phenocrysts consist of plagioclase,

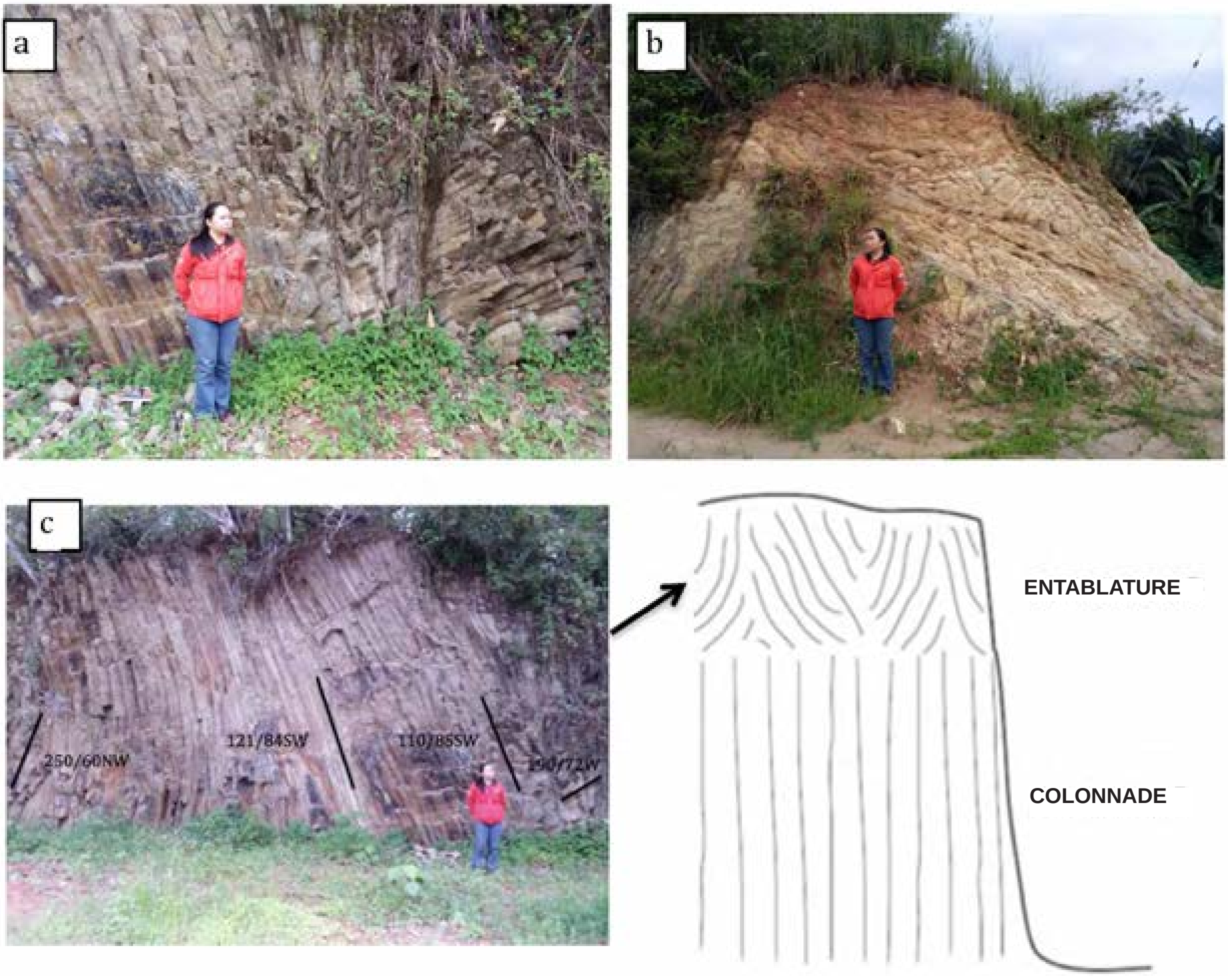

Figure 2: (A) Columnar dacite has characteristic of entablature. (B) Columnar dacite is overlain by dacitic lavas. (C) Top columnar joint (entablature) which similar with columnar dacite. (Illustration after Daniels *et al.*, 2013).

Figure 3: Dacite shows light greyish and slightly weathered.

quartz, hornblende, alkali feldspar, Ti-magnetite, and minor orthopyroxene, enclosed by quartzo-feldspathic groundmass or matrix. Plagioclase is subhedral with sizes ranging from 0.1 – 0.4 mm, and albite twinning is common. Some of the plagioclase showing weak foliation (Figure 4c), zoning (Figure 4d) and alteration to sericite (Figure 4e). Hornblende phenocrysts shows subhedral to euhedral in shape and ranging from 0.2 – 0.6 mm, brown (plane-polarize light), and strongly pleochroic (Figure 4b). Hornblende also shows perfect cleavage exhibits two sets of cleavage with the intersection of approximately 124/56 and has an inclusion of quartz (Figure 4d and 4F). The margin of most hornblende phenocrysts is altered to a secondary mineral such as biotite. Quartz phenocrysts are subhedral to anhedral ranging from 0.1 – 0.15 mm, and some appear to fill up the crack or spaces in plagioclase and hornblende phenocrysts. The groundmass for dacites comprises quartz, alkali feldspar, plagioclase, sericite, and minor iron oxides.

MODE OF FORMATION AND MORPHOLOGY OF COLUMNAR JOINTS

Columnar joints in volcanic rocks were formed during the cooling process of hot lava. The resulting structures usually cut the rock into either quadrangular, pentagonal, or hexagonal prisms (Xia *et al*., 2020). The columnar joints could vary from a few millimeters in diameters to a few meters, while the length could extend up to dozens of meters (Weinberger & Burg, 2019). The formation of these columnar joints could be related to differences in the contraction of the composite rock-forming materials relative to the adjoining parts. The differences in contraction develop as a result of the rapid cooling of the lava, initiating tensile stress, which becomes higher than the maximum stress that the material can withstand before failure, which eventually starts the joints (Pollard & Aydin, 1988). The joint formation occurred from thermal stress resulting from the contraction during the lava's cooling and solidification processes (Pollard & Aydin, 1988). The formation is such that the joints' tip usually follows the solidifying front as the lava cools. As the surface joints form, it propagates inward towards the center of the material in a cyclic manner and leaves behind a trace of the ordering process in a prismatic column formation (Aydin & DeGraff, 1988). Budkewitsch & Robin (1994) and Goehring & Morris (2008) inferred that the columnar joint scaling is such that the column width is inversely proportional to the cooling rate.

COMPARISON BETWEEN COLUMNAR DACITE AND COLUMNAR BASALT IN TAWAU

Columnar basalt is discovered along the Balong River in Tawau. The exposure of columnar basalt does not associate with any types of volcanic rocks in the Semporna Peninsula. The length column for basalt is relatively more significant from half a meter to almost 1 meter (Sanudin *et al*., 2010) (Table 1). On the contrary, the length of the columnar dacite is less than 25 cm. It appears that the diameter for columnar basalt is more than twice bigger compared to columnar dacite. Based on the observation in the field, columnar basalt shows a colonnade feature with regular columns and near-planar sides, while columnar dacites exhibit entablature features. Both columns are showing pentagon to hexagon sides.

CONCLUSION

The columnar dacite occurrences in Tawau, Semporna, shed some light on the columnar jointing associated with supercooling magmatic-hydrothermal environments. Even though the vicinity of the study area is surrounded by felsic volcanic rocks, the columnar jointing is only exposed in these small scales. The possibility of finding another columnar jointing of different types of rocks might be possible since columnar basalt occurs in the Tawau area. Based on the characteristics of columnar dacite, it has an entablature signature with thinner and curving columns. Columnar jointing dominated by hexagon sided with minor pentagons to heptagon sides. The columns are much smaller compared with columnar basalt Tawau. The general mineralogy of columnar dacite is consists of fine-grained, porphyritic, and aphanitic textures.

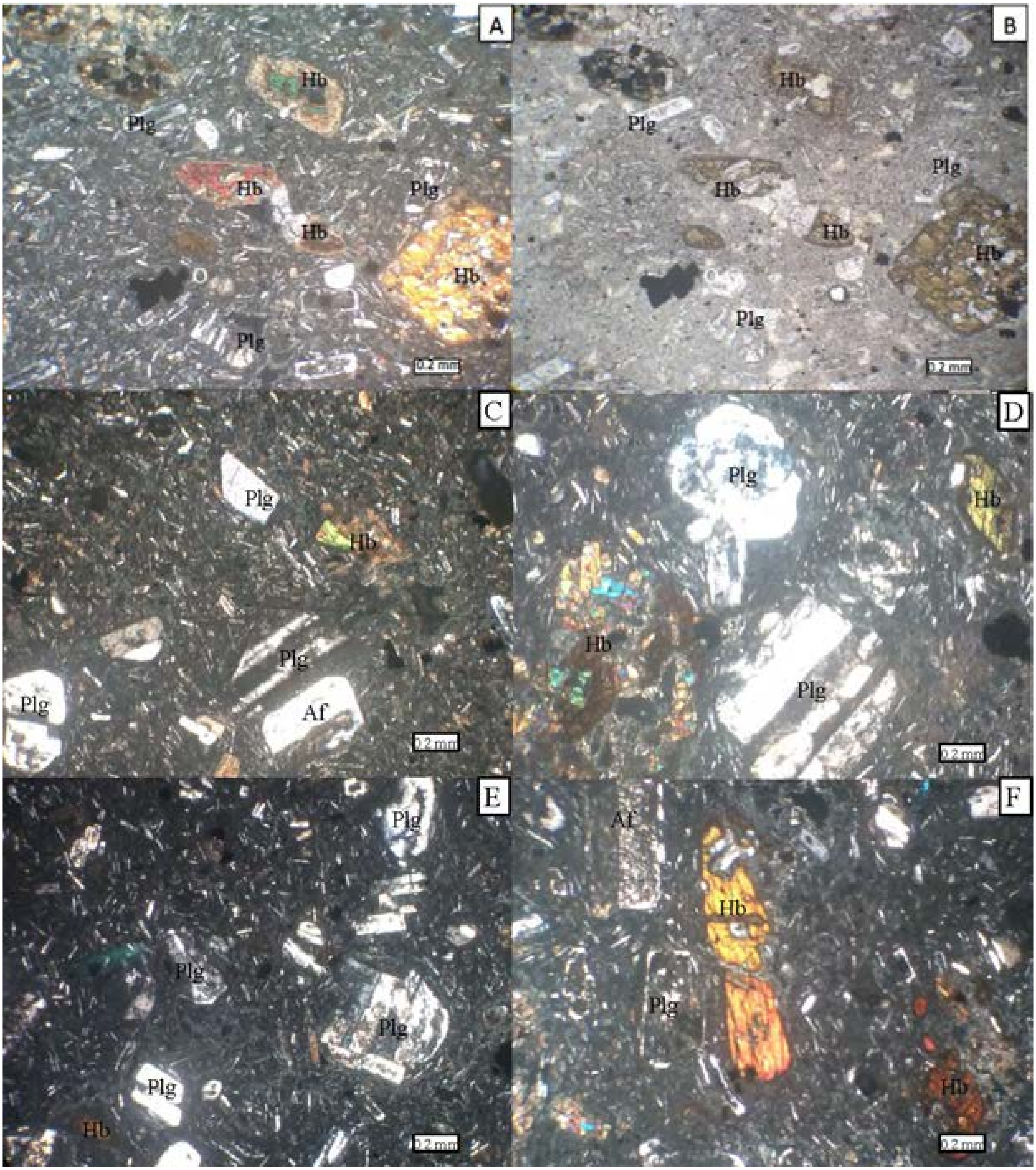

Figure 4: (A) Dacite shows fine-grained, aphanitic, and porphyritic textures. (B) Hornblende phenocrysts showing brown in colour, and strongly pleochroic under the plane polarize microscope. (C) The weak foliation of plagioclase can be seen in dacite. (D) Plagioclase showing zoning in dacite. (E) Some of the plagioclase phenocrysts showing alteration of sericite. (F) Hornblende phenocryst has the inclusion of quartz.

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The geology and stratigraphic framework of the Kuching Zone Sarawak: Current understanding and unresolved issues

Najiatun Najla Mohamad*, Abdul Hadi Abd Rahman, Mohd Suhaili Ismail

Dept. of Geosciences, Universiti Teknologi PETRONAS, 32610 Bandar Seri Iskandar, Perak, Malaysia
*Corresponding author email address: najiatunnajla@gmail.com

Abstract: The geological record of the Kuching Zone extends back in time to more than 300 million years ago. The rock units in the area records a complex history of sedimentation, magmatism and tectonism in the Mesozoic and Cenozoic times. Pre-Upper Carboniferous metamorphic rocks are the oldest rock. Exposure of the younger metamorphic rocks of Late Mesozoic have been assigned to various formations with uncertain protoliths and origin, and have been interpreted to be related to Cretaceous-Cenozoic accretionary setting. Some of the significant events that have occurred include the deposition of clastic sediment with volcanic flow and pyroclastic during Carboniferous to Triassic, and deposition during Jurassic-Cretaceous was siliciclastic-typed sediment. Cretaceous granitoid intruded this sequence before deposition of paralic siliciclastic sediment of Cretaceous to Miocene age. Although the geology of this zone is relatively well studied, many of the interpretations are still debatable due to the complex geology and insufficient biostratigraphic data and dating of the igneous and metamorphic bodies. Several major unresolved issues still remain unanswered. This paper highlights the current understanding and unresolved issues of rock units in Kuching Zone, proposes an updated stratigraphic framework which incorporating igneous and tectonic events, and an updated geological map integrating information from previous published reports and new field investigations.

Keywords: Geology, stratigraphic framework, Kuching Zone, West Sarawak

INTRODUCTION

Sarawak can be divided into three (3) different tectonostratigraphic zones, which are; Kuching Zone (West Sarawak), Sibu Zone (Central Sarawak) and Miri Zone (East Sarawak). The rock units become younger and display a decrease in stratigraphic and structural complexity towards the eastern part (Haile, 1974). Kuching Zone is interpreted to be the northward extension of West Borneo Basement in Kalimantan into Sarawak (Madon, 1999). This zone and the West Borneo Basement are included into the 'West Borneo Block' which was interpreted as part of the Sundaland continental terrane (Hutchison, 1989). The earliest geological study in this research area was a survey carried out in 1845 by Hiram William, a geologist sent by the British Admiralty (Tan, 1993). The early scientific studies in West Sarawak were influenced by the richness of ore minerals.

The rock units in the research area records a complex geological history due to sedimentation, magmatism and tectonism during Mesozoic and Cenozoic times. As mentioned by Tan (1986), undated Pre-Upper Carboniferous Kerait Schist and Tuang Formation were considered to be the oldest rocks in this zone due to similarities with the Pinoh Metamorphic in Kalimantan (Tan, 1986). Exposures of the younger metamorphic rocks of Late Mesozoic age have been assigned to various formations with uncertain protoliths and origin, and have been interpreted to be related to the Cretaceous-Cenozoic accretionary setting. During Jurassic until Cretaceous, deposition of siliciclastic sediments occurred. This sequence was later intruded by the Cretaceous granitoids before the deposition of Cretaceous-Miocene paralic siliciclastic sediments. Triassic sedimentary rocks and the occurrence of volcanic rocks indicate magmatic activity from the Triassic to Early Jurassic. Breaks in the sedimentary records are represented by major unconformities which are apparent between the pre-Upper Carboniferous and Carboniferous-Permian rocks, between the Carboniferous-Permian and Triassic rocks, between Triassic and Upper Jurassic rocks, and between the Upper Cretaceous and Lower Tertiary rocks (Tan, 1986).

Numerous geological researches of different aspects had been carried out in the Kuching Zone, yet the interpretations are still debatable. This report highlights the current understanding and unresolved issues of this zone by utilizing previous published reports. All stratigraphic and geological events data of the area were integrated to reconstruct and update the stratigraphic framework of the region. Field investigations were conducted at outcrops along Jalan Lundu-Bau, exposed along the newly constructed Pan Borneo Highway. The results are incorporated into the updated geological map of the zone.

METHODOLOGY

In this paper, we reviewed and evaluated previous published reports to highlight the current understanding and unresolved geological issues related to this region. Data and information for stratigraphy and tectonic of the Kuching Zone were compared, contrasted and integrated to reconstruct an updated stratigraphic framework, incorporating igneous and tectonic events. Field investigations were conducted to update the geological map based on the current exposed outcrops.

RESULTS AND DISCUSSION

Current understanding and unresolved issues

Even though there has been much research conducted in Kuching Zone, some of the interpretations are still questionable. This research reviews the previous published reports and has identified some of these issues. Table 1 lists the major rock units occurring in this zone, summarizing the current understanding and unresolved issues.

Stratigraphic framework

The reconstruction of stratigraphic framework of Kuching Zone (West Sarawak) proposed in this paper involved data from stratigraphic and tectonic events. For stratigraphic analysis, four (4) sources have been evaluated, which are stratigraphic columns generated by Tan (1986), Tate (1991), Geological Survey of Malaysia (1995) and Hutchison (2005), as shown in Figure 1.

The stratigraphic column by Tan (1986) differentiate the occurrence of rock units in three different areas – eastern, central and western. The Sebangan and Serian Volcanic Formations were not included. Stratigraphic gaps, igneous rock unit and tectonic events were not defined. The types of lithology are shown, however the boundary and contact for the different rock formations were not included. Tate (1991) has conducted a research to investigate the correlation of rock units in Sarawak and Kalimantan. The stratigraphic column includes rock units of different areas in Sarawak and Kalimantan. However, his table lacks some formation, which are Sebangan, Sejingkat, Serabang and Kayan Sandstone Formations. Kerait and Tuang Formation were placed under one unit

Table 1: The current understanding and unresolved issues on the geology of Kuching Zone.

Carboniferous metamorphic basement
Current understanding: • Kerait Schist was older than Terbat Formation due to its metamorphic characteristics and it is more strongly deformed (Pimm, 1965). • Based on the discovery of the schists, it is believed that the protolith is sedimentary rocks of deep marine turbidite environment (Hutchison, 2005).
Unresolved issues: • There is no proper age dating conducted to this metamorphic basement (Tan, 1986; Tate, 1991). The Pinoh Metamorphic is also undated and assumed to be Paleozoic (Breitfeld *et al*., 2017), thus the interpretation is unsatisfactory. • Their contacts have never been reported.
Upper Triassic rock units
Current understanding: • The sedimentary formations represent sediments derived from a landmass that was dominated by the active Serian Volcanic arc and deposited in adjacent neritic seas (Hutchison, 2005). • Serian Volcanic Formation is reported to be interfingering with the Triassic Sadong Formation (Wilford & Kho, 1965) and is therefore concluded to be Triassic (Breitfeld *et al*., 2017). • Jagoi Granodiorite reported as I-typed granitoids (Ting, 1992) and local alteration resulting in silicification, sericitization and chloritization (JICA, 1985). • Sadong Formation is interpreted to represent an estuarine to neritic deposit with periodic brackish water influence (Lietchi *et al*., 1960 and Wilford & Kho, 1965) interpreted as Triassic due to discovery of Krusin flora with Cathyasian affinity (Kon'no, 1972).
Unresolved issues: • Jambu Volcanics are lithologically similar to the Serian Volcanics (Tate, 1991), however their relationship remains unknown. • Age dating and reported a wide range of ages for the Jagoi Granodiorite (Breitfeld *et al*., 2017). • A strong unconformity between the Sadong Formation and Terbat Formation is still doubted and Hutchison (2005), suggests that the contact maybe locally faulted.

Upper Jurassic and Cretaceous formations

Current understanding:

- The Sadong Formation overlies the Serian Volcanic Formation at the eastern part; to the western part of the research area, the Sadong unit is overlain unconformably by Pedawan and Bau Limestone Formations (Hutchison, 2005).
- Foraminifera was identified in the Bau Limestone Formation and this fauna indicates a general Upper Jurassic age and marked uniformity over a wide area (Bayliss, 1966).
- Bau Limestone Formation is considered to be continental shelf deposit, supported by the discovery of corals (Hutchison, 2005).
- The Pedawan Formation generally overlies the Bau limestone and contains contemporaneous volcanic material (Wilford & Kho, 1965 and Supriatna *et al*., 1993) it indicates a switch from a calcareous shallow marine environment to a clastic-dominated deeper marine depositional environment (Breitfeld *et al*., 2017).
- Pedawan Formation reported had undergone strong thermal metamorphism of the pyroxene hornfel facies (Tan, 1993).

Cretaceous formations

Current understanding:

- The shale of mélange matrix has yielded radiolarian and eleven (11) taxa have been identified (Jasin & Madun, 1996 and Jasin, 2000) and suggests the Serabang Formation as Serabang Complex.
- The Sejingkat Formation shows strong similarities with rock units in Lupar Valley, and has been suggested to be of Mesozoic age, probably Early Cretaceous (Tan, 1979).

Unresolved issues:

- Long range radiolarian ages reported was found in the chert. Thus, the age of Sejingkat Formation is uncertain (Wilford, 1965).
- The existence of Sebangan Formation is questionable due unexposed outcrops. There is no fossil reported and no age dating was ever done.

Upper Cretaceous and Tertiary formations

Current understanding

- Three palynological zones were erected for the Kayan Sandstone (Muller, 1968). The presence of bivalve fossil, and the discovery of pollen indicates that the formation is a delta deposit of Late Cretaceous to Early Eocene age.
- Lithological variations of Silantek Formation were reported and thus, proposed three distinct members: namely the Basal Sandstone Member, Temudok Member and Upper Silantek Redbed Member (Tan, 1982).
- Fossils that can be found in Silantek Formation are bivalves, echinoids, foraminifera, gastropod, nano-fossil, and several type of plant fossils.
- Plateau sandstone in the Bako peninsular, interpreted the succession to be deposits of alluvial sandy braided channel system with high bedload. Johansson (1999) proposed a new name, the Bako Sandstone which is a sub-group of the Bako Sandstone Group.

Unresolved issues:

- Silantek Formation was interpreted to overlie unconformably upon the Sadong Formation and Serian Volcanic Formation; however, no contact has been reported (Hutchison, 2005).
- The relationships between the Tertiary Kayan, Silantek, Plateau Sandstone and Bako Formations have never been discussed.

Cretaceous plutonism

Current understanding:

- Cretaceous plutonism consists of granite, gabbro, dolerite and hybrid rocks, where hybrid rocks are formed by extensive reaction produced by gabbro and Cretaceous intrusion (Kirk, 1968).
- Plutonic rocks are mostly confined to the southern section of Kuching zone.

Unresolved issues:

- The calc-alkaline series in West Sarawak reported was formed by predominantly felsic plutonic rocks. However, the tectonic significance is unknown (Hutchison, 2005).

Tertiary intrusive

Current understanding:

- The Tertiary and Cretaceous intrusive rocks in Kuching Zone are probably genetically related. They show geochemical characteristics corresponding to both high-K calc-alkaline and calc-alkaline rocks (Tan, 1993).

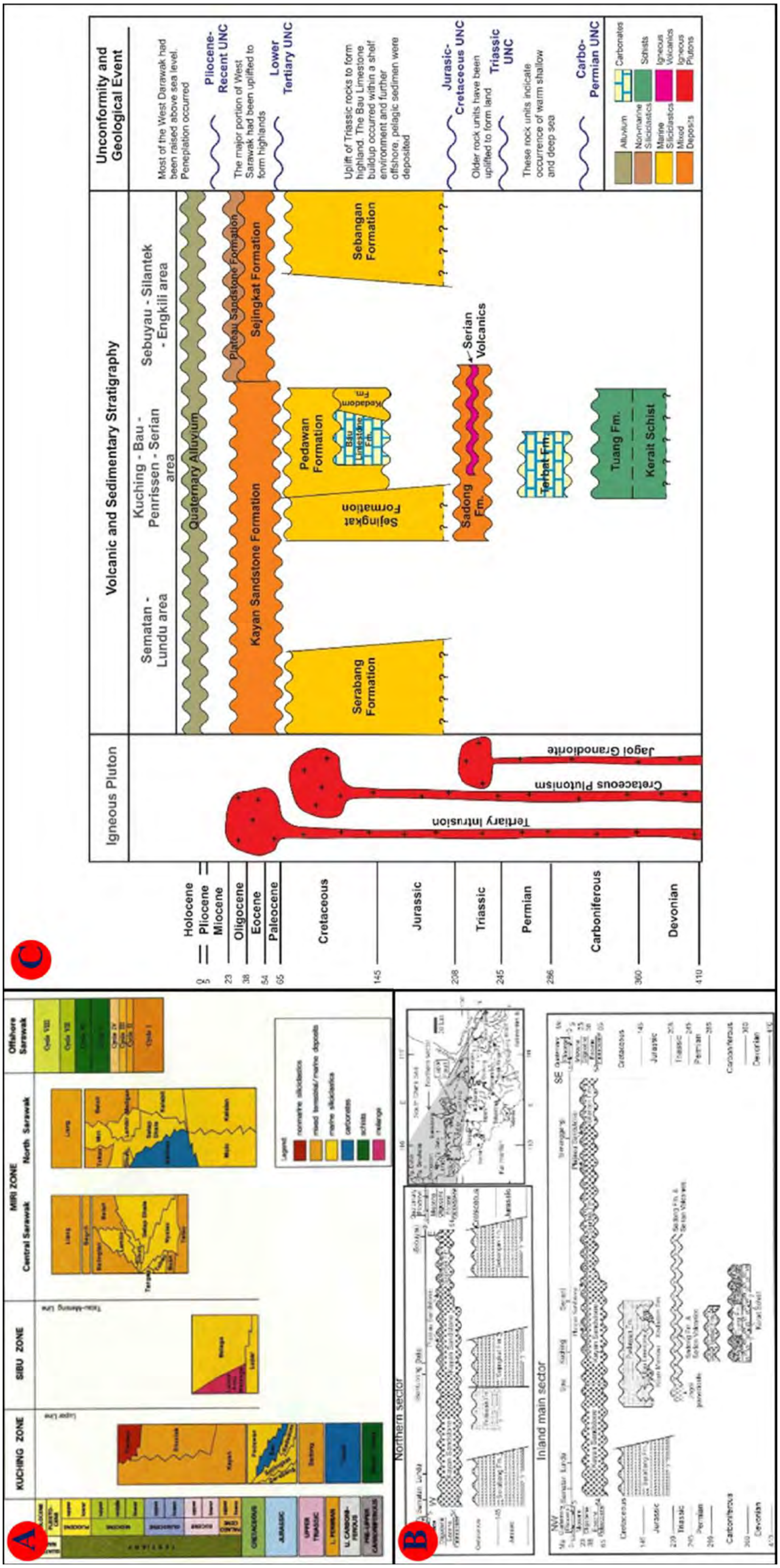

Figure 1: Stratigraphic charts and frameworks by (A) Geological Survey, 1995; and (B) Hutchison, 2005. Figure 1C is a newly proposed, updated stratigraphic chart based on the incorporation of published data, which includes igneous bodies and tectonic events.

and the intercalation of Serian Volcanic with Sadong Formations were not displayed. No unconformities, igneous rock units and tectonic events are indicated.

The stratigraphic column by the Geological Survey of Malaysia (1995) is a simple stratigraphic column that included every zones present in Sarawak (Madon, 1999). There are no unconformities, igneous units and tectonic events shown. Sebangan and Serian Volcanic Formations are not included, and Kerait Schist and Tuang Formation are considered as one-unit rock of pre-Upper Carboniferous age. While, Hutchison (2005) also attempted to compile data from previous research into a stratigraphic column. He divided the Kuching Zone into two different sectors, which are northern main inland, and northern coastal sectors. The stratigraphic column identifies the unconformities and determines the stratigraphic gaps present, and also igneous rock units. However, there is no description on tectonic events and some formations are excluded – these are the Silantek and Kayan Formations. However, this is the most updated stratigraphic chart.

All the four stratigraphic charts show some differences; all charts do not incorporate the tectonic events and the major igneous rock units, the Cretaceous-Tertiary Intrusion and Jagoi Granodiorite.

Paleogeographic development studies conducted by Tan (1986) has divided the Kuching Zone into five (5) time spans. These are Carbonaceous-Permian, Triassic, Jurassic-Cretaceous, Lower Tertiary and Pliocene-Pleistocene. During Carbonaceous-Permian times, rock distribution in the research area was limited; these rock indicated the occurrence of warm shallow and deep water. These rock have been uplifted and widespread subaerial volcanism gave rise to Serian Volcanics during Triassic. During Jurassic-Cretaceous age, Triassic rocks were uplifted to form highlands. The Bau Limestone build-up occurred within a shelf environment; further offshore, pelagic sedimentation resulted in the Sejingkat Formation, Serabang Formation and Sebangan Formation. Major portion of the West Sarawak had been uplifted by the Lower Tertiary and by Pliocene-Pleistocene, most of the West Sarawak had been raised above sea level.

In this paper, we propose an updated stratigraphic framework, which includes the rock units distribution, unconformities, igneous rock units, alluvium and significant geological events, based on the incorporation of data from published reports.

Geological map

Field investigation were conducted on the outcrops exposed due to the construction of Pan Borneo Highway along Jalan Lundu-Bau. The results from this investigation were integrated into previously published geological map. There are six (6) previous geological maps of the Kuching Zone identified which were generated by Haile (1954), Wilford (1955), Lietchi *et al.* (1960), Tan (1979, 1993) and Breitfeld *et al.* (2017). Maps produced by Haile (1954) and Wilford (1955) are the early versions of detailed maps of the area. Lietchi *et al.* (1960) published the first geologist map of Sarawak, including Brunei and North Borneo. The classification of rocks in these early maps are based only on their lithology and age, without the proper nomenclature of the sedimentary formations. Tan (1986) carried out a detailed study on the geology of the zone together with the classification of the rocks according to sedimentary formation and their respective ages. Tan (1979, 1993) mapped and categorized the igneous plutons in this zone into Cretaceous Igneous and Tertiary Igneous. He also mapped and classified the different sedimentary formations within West Sarawak. Breitfeld *et al.* (2017) updated the geological map of West Sarawak. However, they did not include some sedimentary formations.

We incorporated new data from recent fieldwork into the previous maps to produce an updated geological map.

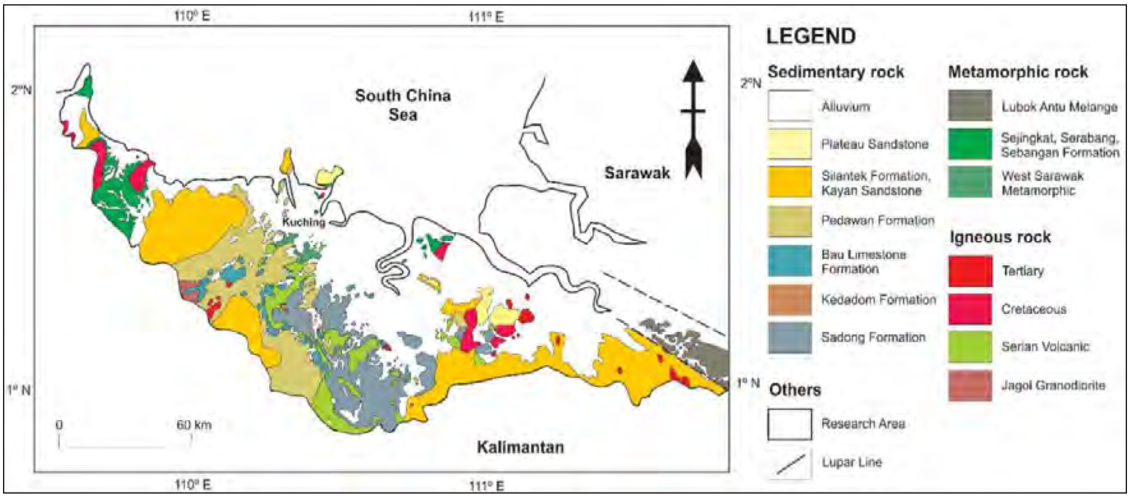

Figure 2: An updated geological map of Kuching Zone (West Sarawak).

Based on the mapping conducted, some areas at Jalan Lundu-Bau exposed sections of the Kayan Sandstone Formation. The outcrops showed thick cross-bedded sandstone instead of alluvium; this contradicted the information on lithology given from the previous maps. Figure 2 shows the updated geological map of Kuching Zone.

CONCLUSION

The geology of Kuching Zone is very complex, and the interpretations concerning the geological history are still arguable and not fully resolved. This paper compiled and summarized the current understanding and unresolved issues of this zone by utilizing previous published reports. This paper has also incorporated stratigraphic and tectonics data from the previous published report to produce an updated tectonostratigraphic framework of Kuching Zone, which incorporated significant geological and plutonic events. This framework includes the distribution of rock units, unconformities, igneous rock units, alluvium, and significant geological events. A revised geological map of Kuching Zone is proposed by integrating six (6) published geological maps and updated with data from field investigation, which were conducted at the outcrops within Jalan Lundu-Bau exposed due to the Pan Borneo Highway construction. The extension of Kayan Sandstone Formation has been recognized, which this area was previously mapped as alluvium. As for recommendations, this paper propose detail biostratigraphic and structural studies on the Kuching Zone (West Sarawak) to be carried out in the future. These studies may help to resolve many of the highlighted issues in this paper.

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Earth crustal analysis of Northwest Sabah region inferred from receiver function method

Abdul Halim Abdul Latiff*, Faridah Othman

Geosciences Department, Universiti Teknologi PETRONAS, 32610 Bandar Seri Iskandar, Perak, Malaysia
*Corresponding author email address: abdulhalim.alatiff@utp.edu.my

Abstract: Many methods are used to investigate the Earth's crustal with the knowledge of geology and geophysics. Earth crustal analysis beneath the Kota Kinabalu region, located in Northwest Sabah, was performed by using tele-seismic earthquakes as sources. While Sabah geology is highly complex the understanding of its tectonic history has remained ambiguous. The tomography of the Kota Kinabalu region is mainly influenced by the collision between the South China Sea and Sabah margins during the Early Miocene which leads to crustal thickening. At present, the subsurface properties, and structures underlying the Kota Kinabalu region are yet to be recognized. Thus, this study aims to acquire the crustal properties beneath the Kota Kinabalu region through the deployment of a weak-motion seismometer station within the Crocker Range, Sabah, Malaysia. Additionally, the work conducted is to determine the thickness and velocity layer of the Earth's crust up to the Moho boundary. Receiver function analysis was chosen as the method to conduct this study where responses of tele-seismic earthquakes recorded at KKM station were evaluated and processed through 2D rotation, iterative time deconvolution, signal-to-noise ratio analysis, stacking, H-k analysis, as well as forward modelling and waveform inversion. A total of 916 time series data were retrieved from International Seismological Centre (ISC)'s respiratory with only 184 receiver functions were incorporated in this study whereas the remaining 732 receiver functions were deemed noisy and unfit for the next process. The selected receiver functions have an earthquake magnitude greater than 6 mb with a signal-to-noise ratio of greater than 5. The processing steps included in this study are conducted by using open-source computation programs such as Seismic Analysis Coding (SAC) and Generic Seismic Application Coding (GSAC). From the 1-D velocity models inferred from receiver function inversion, the subsurface structural framework and velocity anomalies within the crust beneath the station were interpreted and analysed. With the additional information generated from H-k analysis, it is interpreted that the Earth subsurface beneath the Kota Kinabalu region has the Conrad discontinuity at 26 km depth, the Moho boundary at 40 km depth while the Lithosphere-Asthenosphere boundary was found at 66 km below the surface level. Additionally, the velocity profiles within the Kota Kinabalu's crust show alternating patterns with V_P has the range between 5 km/s to 7 km/s, and V_S has the range of 3 km/s to 4 km/s. The V_P and V_S readings reached 8 km/s and 4.5 km/s respectively as it hits the Moho boundary at 40 km depth.

Keywords: Receiver function, crustal thickness, velocity structure, Kota Kinabalu

INTRODUCTION

Sabah is located on the NE of Borneo island in East Malaysia where the Eurasian, Pacific, Philippines, and Indo-Australian plates meet. It is centrally positioned between three marginal basins which are Sulu, the South China Sea, and Celebes (Balaguru & Hall, 2009). The understanding of the tectonics of Sabah has always been ambivalent due to its geological complexity, with south-easterly subduction in the NW Borneo, and extension in the SE in the Celebes Sea and Makassar Strait (Pubellier & Morley, 2014). 45 million years ago, the southwards subduction of the oceanic crust of proto South China Sea occurred along an active continental margin that extended from northeast Sarawak through Sabah towards the northern Philippines (Metcalfe, 2011). Concurrently, the continental crust of the South China margin is pulled and eventually separated from the Eurasian continent. Subduction of the Proto-South China Sea beneath Sabah terminated soon after the collision of the South China margin with Sabah margin (Figure 1a) (Metcalfe, 2017). The collision between South China Sea margin and Sabah margin during Early Miocene believed to thicken the lithosphere which later penetrated the mantle before separated as a blob which causes an uplift as a result of equilibrium re-establishment (Hall *et al.*, 2008).

On the other hand, the Sabah state capital, Kota Kinabalu, is situated at NW of Borneo along the region where the continental-continental collision occurred. It is underlain by the Late Eocene-Lower Miocene Crocker Formation and Quaternary Alluvium. The collision

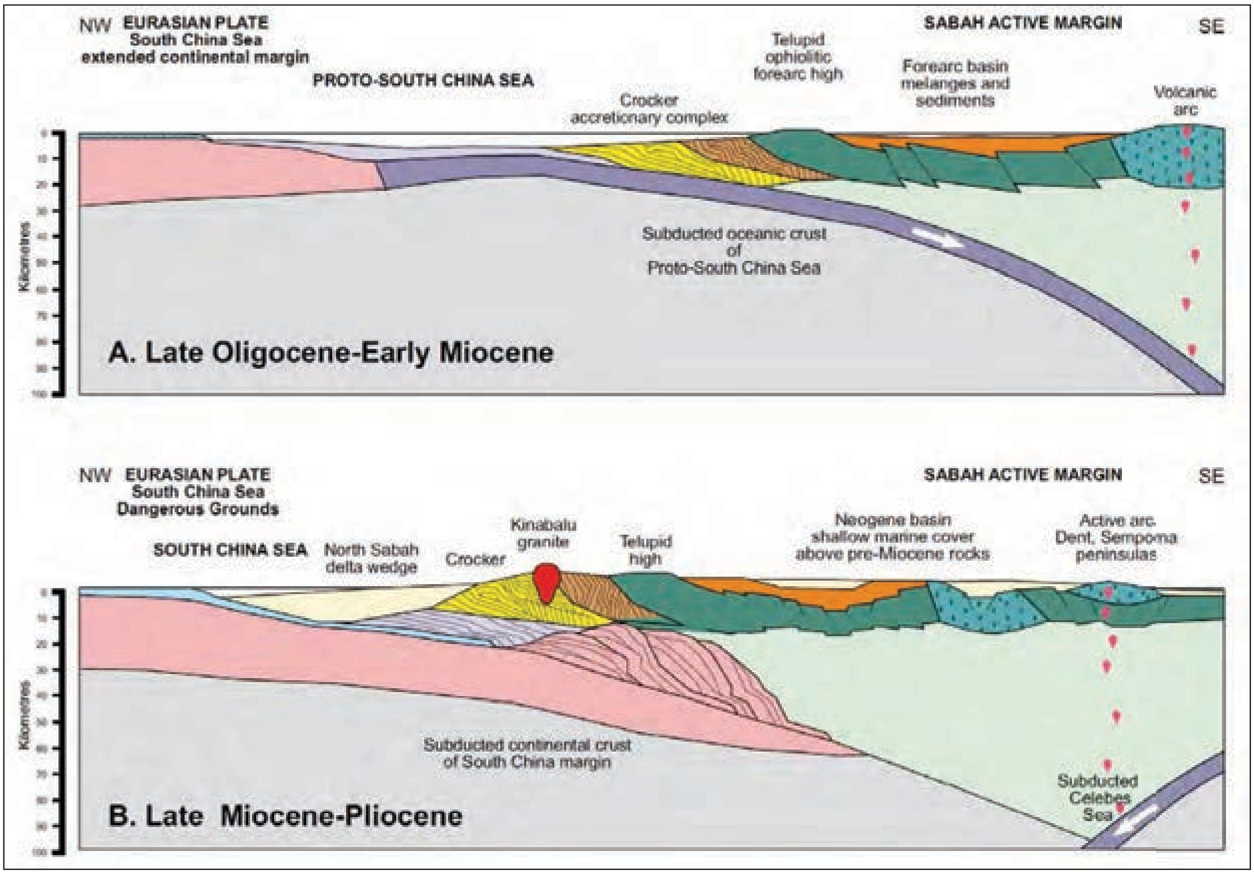

Figure 1: Illustration of subduction of proto-South China Sea (Hall *et al.*, 2008).

between the South China Sea margin and Sabah margin in the Early Miocene eventually uplifted the Crocker formation above sea level and thus, allowing erosion to occur which then formed an unconformity (Figure 1b). A broad range of mountain belt is created along collision margin and although some of the mountain range remained along with the Crocker ranges, most of the areas in the north and south are lowered below sea level due to subsidence.

The absence of a crustal-mantle model in the Kota Kinabalu region leads to an ambiguous understanding of the topography of the study area. Previous studies only hypothesized crustal thickening due to continental-continental collision of the South China Sea and Sabah margins based on the features of surface geology (Sidek *et al*., 2016). The actual crustal thickness and subsurface properties such as the velocity profile beneath the Kota Kinabalu region are not yet explored. Thus, this research aims to analyze the crustal properties beneath the Kota Kinabalu region, as well as to determine the thickness of the Earth's layer above the Moho boundary and to evaluate the velocity profile within the Earth's crust of the study area.

The Kota Kinabalu seismometer station (KKM) used for the study is located at latitude and longitude of 6° 2' 39.48'' N and 116° 12' 52.9164'' E. Geographically, the western side of Sabah where Kota Kinabalu is located is mostly of the mountainous region. This region of high elevation is a part of the Crocker range which separates the East Coast and West Coast of Sabah. The highest elevation is around 4000 m above sea level which is Mount Kinabalu situated 80 km northeast of Kota Kinabalu. KKM station is located at an elevation of about 810 m above sea level (Figure 2).

The principle of isostasy states that the gravitational equilibrium between the Earth's crust and mantle is achieved such that the crust floats on a denser underlying mantle at an elevation depending on its thickness and density. Based on Airy's theory, the rock density across the lithosphere is almost similar, but the crustal blocks have different thicknesses and densities (Pan, 2007). Therefore, a highly elevated crust (e.g. mountainous region) depicts a thicker and denser crust whereas a low elevated crust (e.g. basin and lowlands) indicates a thinner and less dense crust.

The method of study is Receiver Function Analysis which is a passive seismic technique that utilizes responses from tele-seismic earthquakes. In receiver function analysis, data processing such as 2D rotation, iterative time-domain deconvolution, Gaussian filter, and

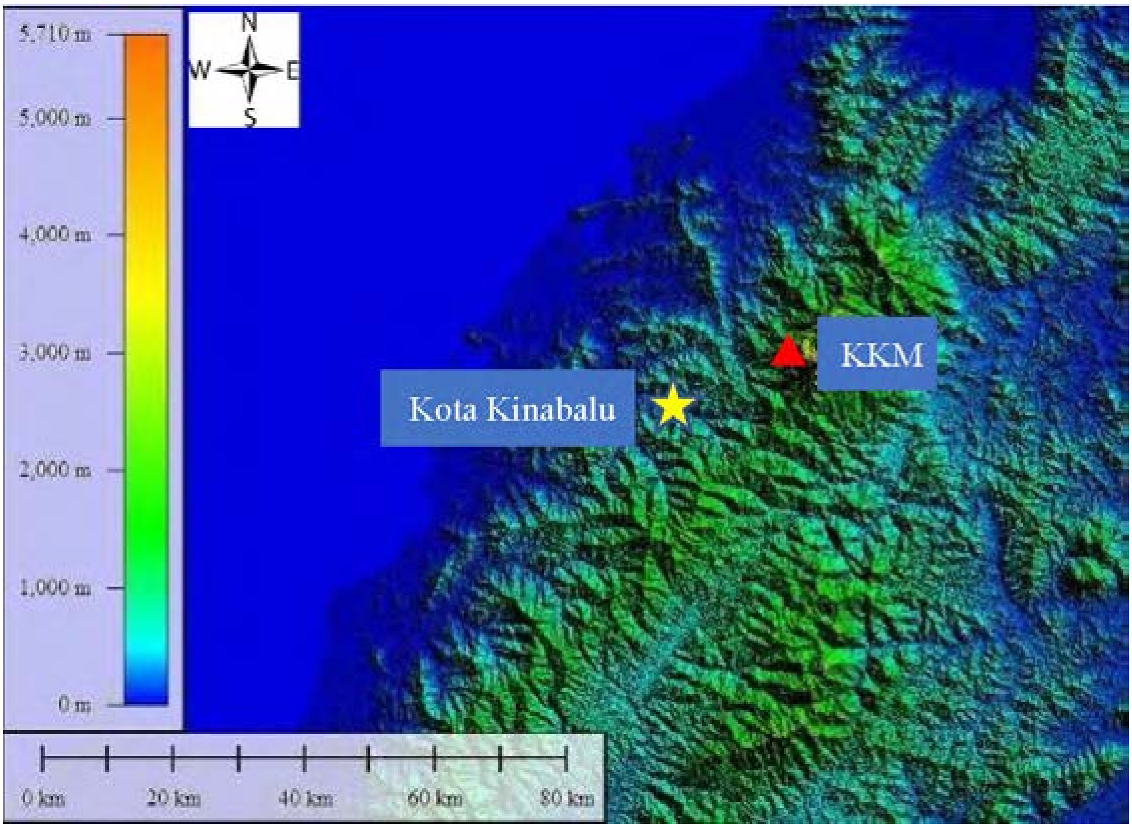

Figure 2: Digital elevation map of Kota Kinabalu region, showing the location of KKM station.

signal stacking are applied. Elimination of noisy data are done via signal-to-noise ratio (SNR) analysis. The crustal thickness (H) and average primary to secondary velocities (Vp/Vs) ratio (k) are estimated by using the H-k analysis technique. This study also includes forward modelling and waveform inversion to create ideal 1-D velocity models that represent the Earth's subsurface properties beneath KKM station (Abdul Latiff & Khalil, 2016). The data processing and modelling in this study are carried out using computer programs such as Seismic Analysis Code (SAC) and Generic Seismic Application Coding (GSAC) which runs in Linux Operating System. Programming codes written and used throughout the study were adopted from Herrmann & Ammon (2002).

METHODOLOGY

Receiver functions are time series data recorded by a 3-component broadband seismometer (Langston, 1977). The receiver function method uses earthquakes as a source of seismic body waves such as P-wave and S-wave to infer on the Earth's structural framework. P-wave is the fastest seismic wave travelling at about 4-8 km/sec in the Earth's crust (Abdul Latiff & Khalil, 2019). The motion of particles is parallel to the direction of wave propagation. P-waves can travel through the molten core and fluid-formed layers; liquid or gas, unlike S-waves which can only propagate through solid. S-wave travels at about 2.5-4 km/sec in the Earth's crust which makes it the second-fastest wave. Typically, the velocity of S-waves is around 60% of that P-waves. However, the velocity varies according to the material composition of the medium in which it travels. S waves oscillate particles in a motion that is perpendicular to wave propagation.

These waves are detected by a device called seismometer at the seismic recording station. A seismogram is a record of the ground motion in a graph form (seismograph) at the recording station in a function of time or time series. It records seismic waves in three-cartesian axes (x,y and z) or in three directions: north-south (BHN), east-west (BHE) and vertical (BHZ) (Figure 3). When body waves arrive at a three-component seismometer station, it provides information about the various path travelled by the waveforms. It contains information on the seismic source structure, its propagation through the mantle as well as the structure beneath the seismic recording station.

Typically, the first arriving wave at the recording station is P-waves followed by S-waves and the later multiples; PpPs, PsPs, PpSs (Figure 4). Transmitted P-waves that are reflected at the Moho to the surface are called multiples whereas S-waves are originated from P-waves which are converted and transmitted into

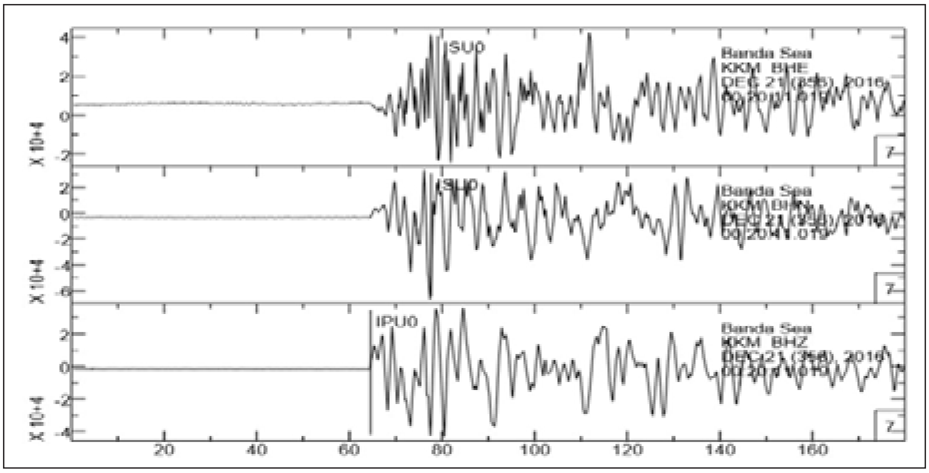

Figure 3: A three-component seismograms at KKM station recorded an earthquake signal originated in Banda Sea.

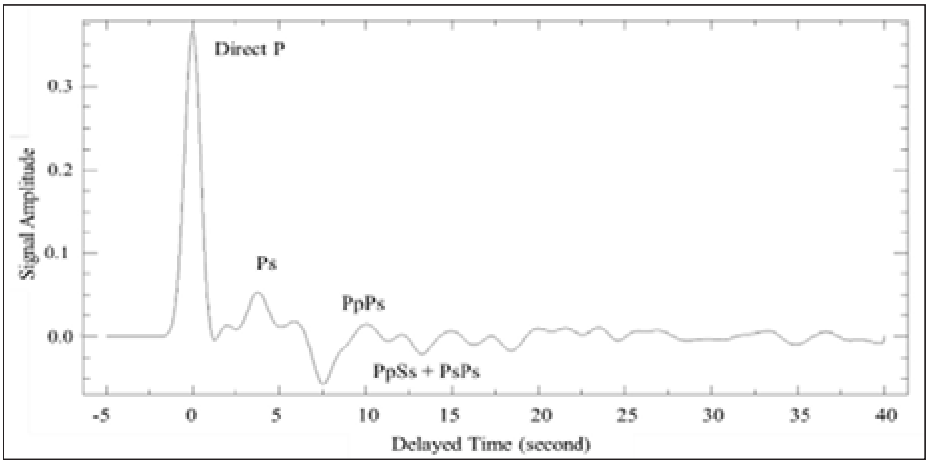

Figure 4: Waveform shows the stack receiver function that was computed at IPM station, with a clear indication of the direct P-arrival, PpPs, PpSs and PsPs multiple phases.

secondary waves as they hit the Moho boundary. The main objective of the receiver function method is to eliminate information on seismic source structure and its propagation path so as to only reserve the information on the local structure beneath the seismic station (Jansson, 2008).

The data used in this research are obtained from IRISDMC (IRIS Data Management Center) using FDSN Web Services. The IRISDMC compiles a record of the Earth's seismicity to support the seismological research community. The selected data are originated from earthquakes with an epicentral distance between 30° to 90° from KKM station and waves magnitude of greater than 6 Mb (body wave magnitude). This is because P-S wave conversion can only take place when the ray path includes both the mantle and the Earth's crust and a higher magnitude of waves produces suitable signal strength. Therefore, 916 time series data from events occurring from the year 2005 to 2016 are retrieved. The location of earthquakes varies within the Earth's Ring of Fire from Pakistan and Central Asia to Japan, New Zealand, and Fiji Islands.

The seismogram is readily cut 60 seconds before and after the arrival of direct P-wave. These steps are done due to the limitations of the program is storing the number of points of data in a file (Kieling *et al*., 2011). Moreover, the data are also down-sampled into a lower frequency and shifted to a zero-amplitude reference line so that it appears to be less noisy with a smaller time interval. Although the data is in a three-component (ZNE) seismic data, the axis between the earthquake and the station is not aligned and thus, a two-dimensional rotation is conducted to isolate the energy of different wave types. P-waves are mostly confined in the vertical component while the converted S-waves are contained in the radial component. Ultimately, the ZNE coordinate system becomes ZRT respectively.

The iterative time-domain deconvolution process is applied to eliminate the effects of near-source structure and source time functions. The platform of iterative time-domain deconvolution is to minimize the difference between the predicted signal and the observed horizontal seismogram (Torsvik, 2015). A normalized Gaussian filter is also applied to eliminate high-frequency noise in the receiver functions. It is observed that a width factor of below 1.0 generates receiver function with undefined spikes whereas the width factor with values greater than 2.5 will produce a noisy receiver function. Therefore, a width factor of 1.5 is used in the filter to produce optimum results.

The ray paths of seismic waves generated from earthquake events respectively are unique and differ from each other. This is because the Earth's layer is non-homogenous. Back azimuth plot allows the comparison of receiver functions (Figure 5). There are a few receiver functions that do not conform with the others. These receiver functions are identified and eliminated from the stack list. Apart from that, the receiver functions with signal-to-noise ratio smaller than 5 are also eliminated. The remaining receiver functions are summated by using the sum-stack technique in SAC. Consequently, only 184 receiver functions are used further in this study.

A typical receiver function study is unable to eliminate the depth-velocity ambiguity because of its shallow range of slowness. The crustal thickness estimated is only based on the delay of time of the P-to-S conversion phase at Moho without considering the crustal Vp/Vs ratio. By applying H-k analysis, we can reduce the depth-velocity ambiguity present. Therefore, a better approximate value of crustal thickness (H) and the mean of Vp/Vs ratio (k) based on the receiver function time series. Apart from that, we can provide a much-detailed diagnostic of crustal composition than P or S-wave data alone.

H-k analysis incorporates the later arriving multiple converted phases, PpPs and PpSs + PsPs with P-to-S converted phases. The amplitudes of receiver function at the estimated arrival times of these phases by different crustal thicknesses, H and Vp/Vs ratios are stacked thus, producing a stacking algorithm (Zhu & Kanamori, 2000). Consequently, the effects of lateral structural variation are diminished, and an average crustal model is obtained. Based on a given earth structure model, the receiver function can be determined through forward modelling. Nevertheless, the aim of this research is not to attain the receiver function but to obtain the true subsurface structure beneath KKM station via waveform inversion. Forward modelling and inversion are conducted simultaneously until the final model is achieved.

In this study, 1-D velocity models via 2-passes receiver function inversion are produced (Julia *et al.*, 2000). The two initial models which are used for the 1st pass inversion and 2nd pass inversion are Earth model with constant velocity and the modified IASP-91 respectively. Several 100 iterations and a smoothness trade-off parameter of 0.4 was designated to generate these velocity models. The time window is set from -5s to 30s of the receiver function waveforms. The first pass receiver function inversion is conducted before the second pass receiver function inversion which resulted in intermediate velocity models. The IASP-91 model is modified based on the velocity trend and significant changes in the intermediate model. According to Incorporated Research Institutions for Seismology (2017), the IASP-91 reference model is a parameterized velocity model that has been constructed to be a summary of the travel time characteristics of the main seismic phases. Subsequently, the second pass receiver function inversion is carried out based on the

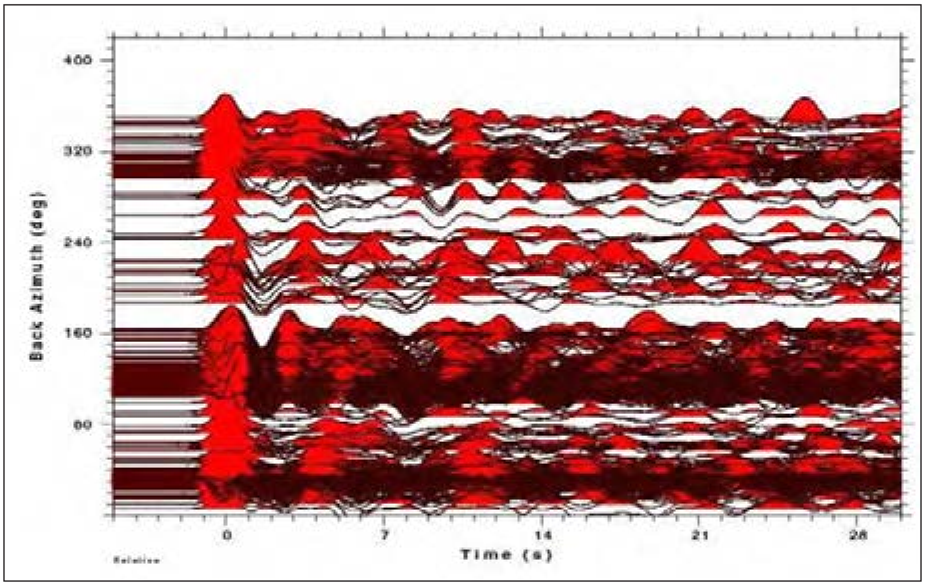

Figure 5: Back azimuth plot of 916 receiver functions, stacked together for waveform analysis.

modified IASP-91 model. The final velocity models are then produced to be interpreted and analysed to infer on the subsurface properties and structural framework beneath KKM station.

CRUSTAL MODEL BENEATH KOTA KINABALU REGION

Receiver functions

The signal-to-noise ratio analysis resulted in eliminating 732 receiver functions from the initial 916 receiver functions extracted from IRISDMC. There were only 184 receiver functions with signal-to-noise ratio of greater than 5. Figure 6 shows back-azimuth plots of the resultant 184 receiver functions. The resultant receiver functions at KKM station show the arrival of Ps converted wave at time 3.5 seconds in the 1st, 3rd and 4th quadrants. Furthermore, the recorded signal with earthquake originated from 270° to 360° back azimuth (4th quadrant) contains an additional weak multiple phase at 7.5 seconds, immediately after the Ps phase. This phenomenon might be due to wave propagation disturbance and /or poor source signature of the earthquakes occurred in India, Pakistan, China, and Russia. At 11 seconds, particularly in the 1st, 3rd and 4th quadrants, PpPs phase is detected. At a later duration, the receiver functions with an earthquake occurring in the 1st quadrant depict relatively weaker PsPs + PpSs multiples at 14 seconds. However, due to noisy and inconsistent waveforms generated from earthquakes from 2nd quadrant, no phase interpretation is made further for this station.

The outcome of the stacking process is the summated stack of observed receiver functions where coherent signals are emphasized, noise is suppressed, and an increase of overall signal-to-noise ratio. It also provides a better representation of the resultant receiver functions. Figure 7 shows the summated stack of resultant receiver functions.

H-k analysis

H-k analysis is a method of estimating the crustal thickness and average Vp/Vs ratio based on the receiver function time series (Torsvik, 2015). The y-axis represents the crustal thickness in kilometres (H), while the x-axis represents the Vp/Vs ratio (k). The result of H-k analysis is portrayed in a contour plot (Figure 8). Each contour plot holds a value of percentile confidence regions accordingly. Based on the analyss, the highest value of the percentile confidence region is 0.95 or 95% which indicates a crustal thickness of about 43 km with a Vp/Vs ratio of 1.55. Therefore, it is assessed that the Moho depth is at a depth of approximately 43 km beneath KKM station. This estimation will be further clarified with the outcomes of forward modelling and inversion processes.

Velocity models

The interactive iterative process of forward modelling and waveform inversion generates velocity models that can be interpreted to give an idea about the subsurface properties and structures underneath KKM station. In this project, 2-passes receiver function inversion is conducted whereby the first inversion produced intermediate velocity models that is analyzed and used to modify the IASP-91 model so to generate the final velocity models from the second inversion. In these models, two lines of the colour red and blue are depicted to represent the input models and

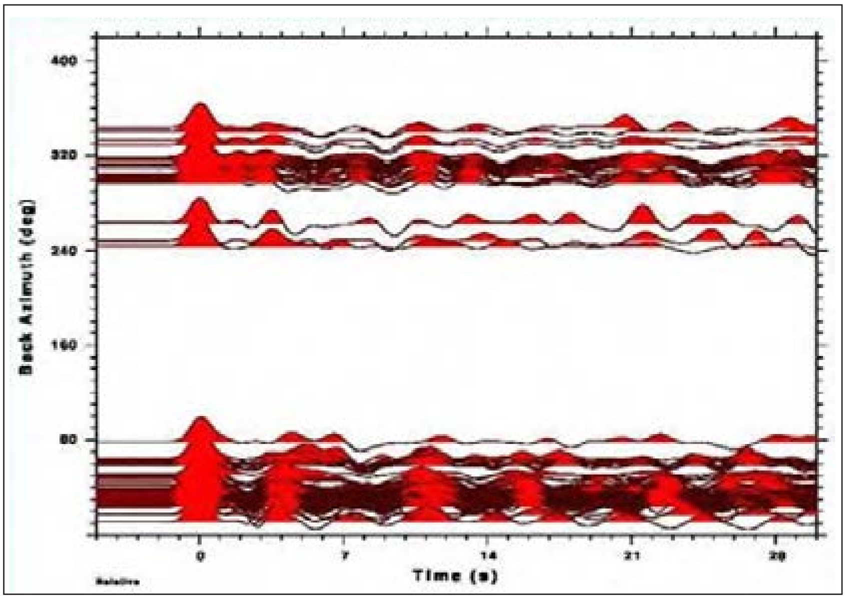

Figure 6: Back-azimuth plots of selected 184 receiver functions, as a result of signal-to-noise criterion implementation.

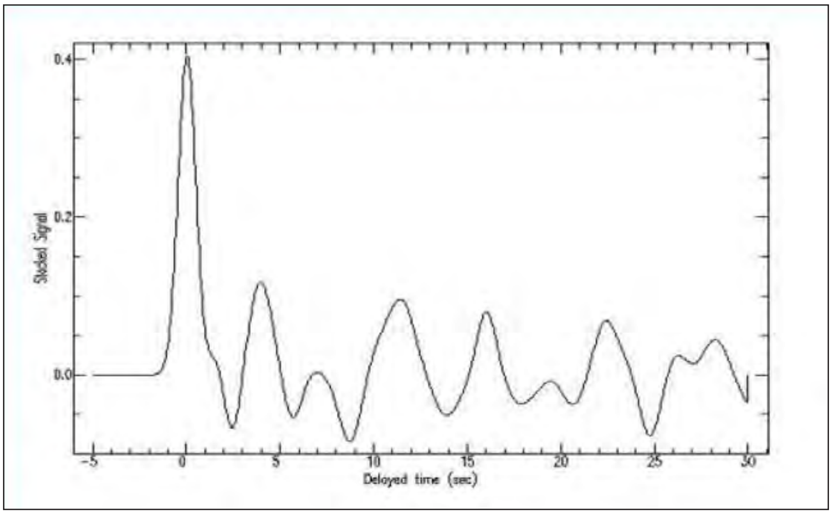

Figure 7: Summated stack of receiver functions of 185 waveforms in Figure 7.

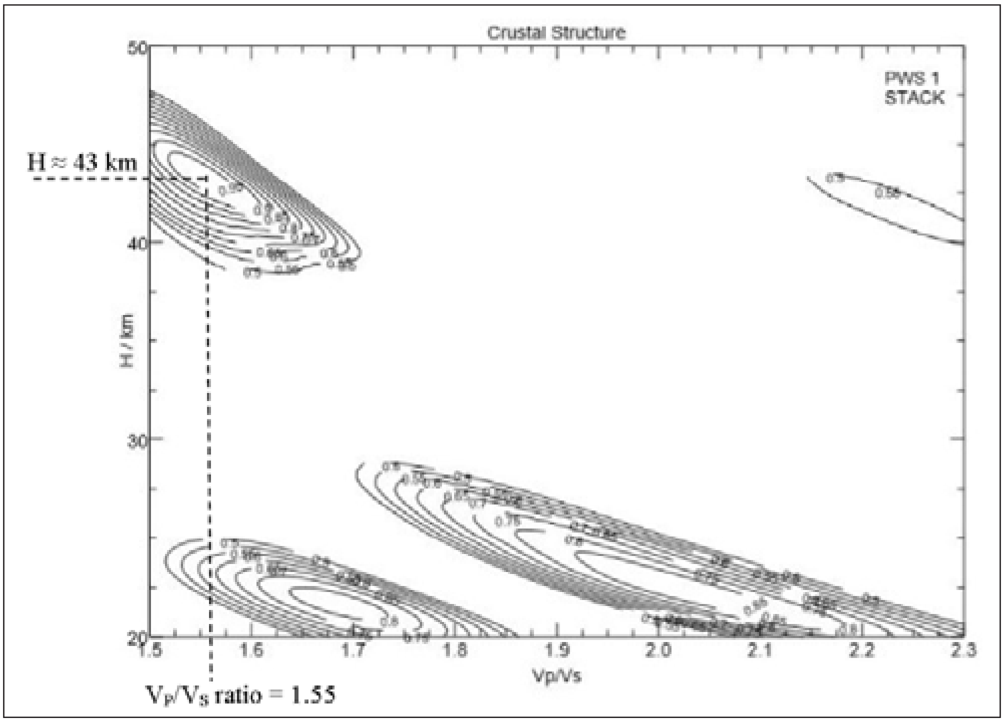

Figure 8: H-k plot analysis indicates the thickness (H) and V_P/V_S ratio beneath Kota Kinabalu region.

the velocity model generated from the receiver function inversion (Figure 9).

Based on the first inversion intermediate velocity models, three significant velocity changes are observed. Firstly, at depth 26 km beneath KKM station, both P-velocity and S-velocity experienced an increase from 6.2 km/s to 6.8 km/s and from 3.5 km/s to 3.9 km/s respectively. Secondly, at depth 40 km, both P-wave and S-wave velocity reached nearly 8.0 km/s and 4.5 km/s which are average velocities of P-wave and S-wave in the upper mantle. Thirdly, both P-wave and S-wave experienced a substantial drop in velocity indicating a low-velocity zone (LVZ).

Consequently, the IASP-91 is modified based on the interpretations of the intermediate velocity models especially at depth 26 km, 40 km, and 66 km. The second and final P-wave and S-wave velocity models for KKM station are depicted in Figure 10. At depth of 26 km beneath KKM station, there is a significant increase in P-wave velocity of the final model from 6.2 km/s to 6.8 km/s as well as an increase in the S-wave velocity from 3.6 km/s to 4.0 km/s. This indicates that

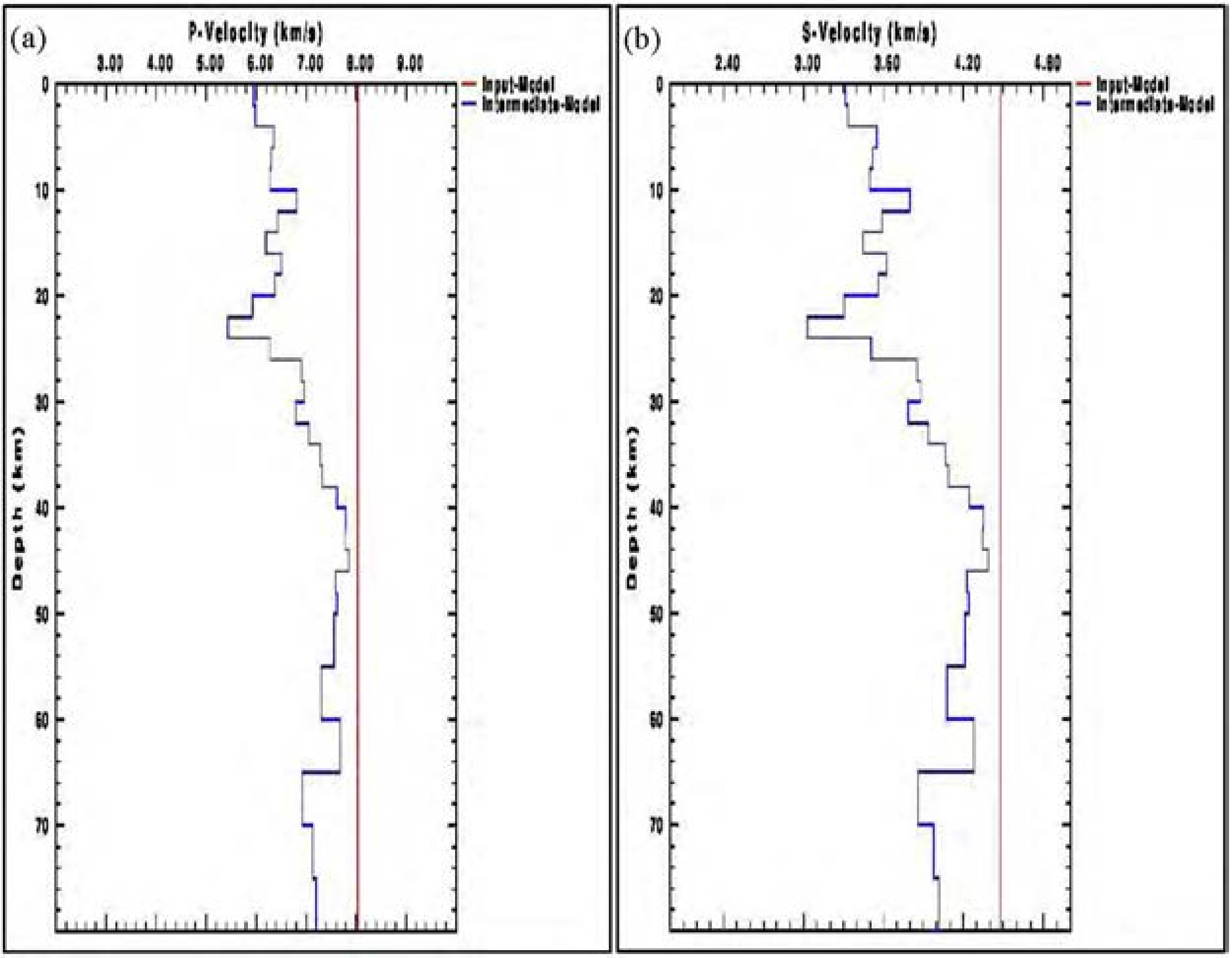

Figure 9: Velocity model after the 1st inversion for (a) P-wave model and (b) S-wave model.

the Conrad discontinuity that exists between the upper crustal layer and the lower crustal layer is detected at 26 km depth. The range of P-wave velocity in the upper crust 5.4 km/s to 6.6 km/s whereas the range of P-wave velocity in the lower crust is 26 km is 6.2 km/s to 7.2 km/s.

Furthermore, at a depth of 40 km beneath the station, both P-wave and S-wave velocities reached 8.0 km/s and 4.5 km/s respectively. The average P-wave velocity in the uppermost mantle should be greater than or equal to 7.6 km/s (Mooney *et al*., 2002). Thus, the Moho boundary is at depth 40 km beneath KKM station. At greater depths of more than 40 km, the P-wave and S-wave velocities decrease linearly. At depth 66 km beneath KKM station, it is observed that both P-wave and S-wave velocities experienced a low-velocity zone which indicates the lithosphere-asthenosphere boundary. The S-wave velocity substantially decreased from 4.3 km/s to 3.7 km/s. A low-velocity zone which generally occurs near the lithosphere-asthenosphere boundary is usually characterized by a huge drop in S-wave velocity. This is because the low-velocity zone signifies a certain degree of partial melting and S-waves are unable to pass through liquids.

Previously, the estimated crustal thickness from H-k analysis is about 43 km beneath the station with Vp/Vs ratio of 1.55. The interpretations of the final velocity models do not vary too much from the results estimations from H-k analysis. Thus, the outcomes from waveform inversion are proven reliable and suitable. Hence, a crustal-mantle model beneath KKM station in Kota Kinabalu is constructed with 40 km of crustal thickness above the Moho boundary (upper crust of 26 km thick and lower crust of 14 km thick). Additionally, the lithosphere-asthenosphere boundary is detected by the low-velocity zone at 66 km depth underneath the station. The crust beneath the Kota Kinabalu region appeared to be thicker than the average continental crust which is about 35 km. This might be due to the crustal thickening that occurred after the continental-continental collision of the South China Sea margin with Sabah margin which also produced a broad range of mountains along the collision margin.

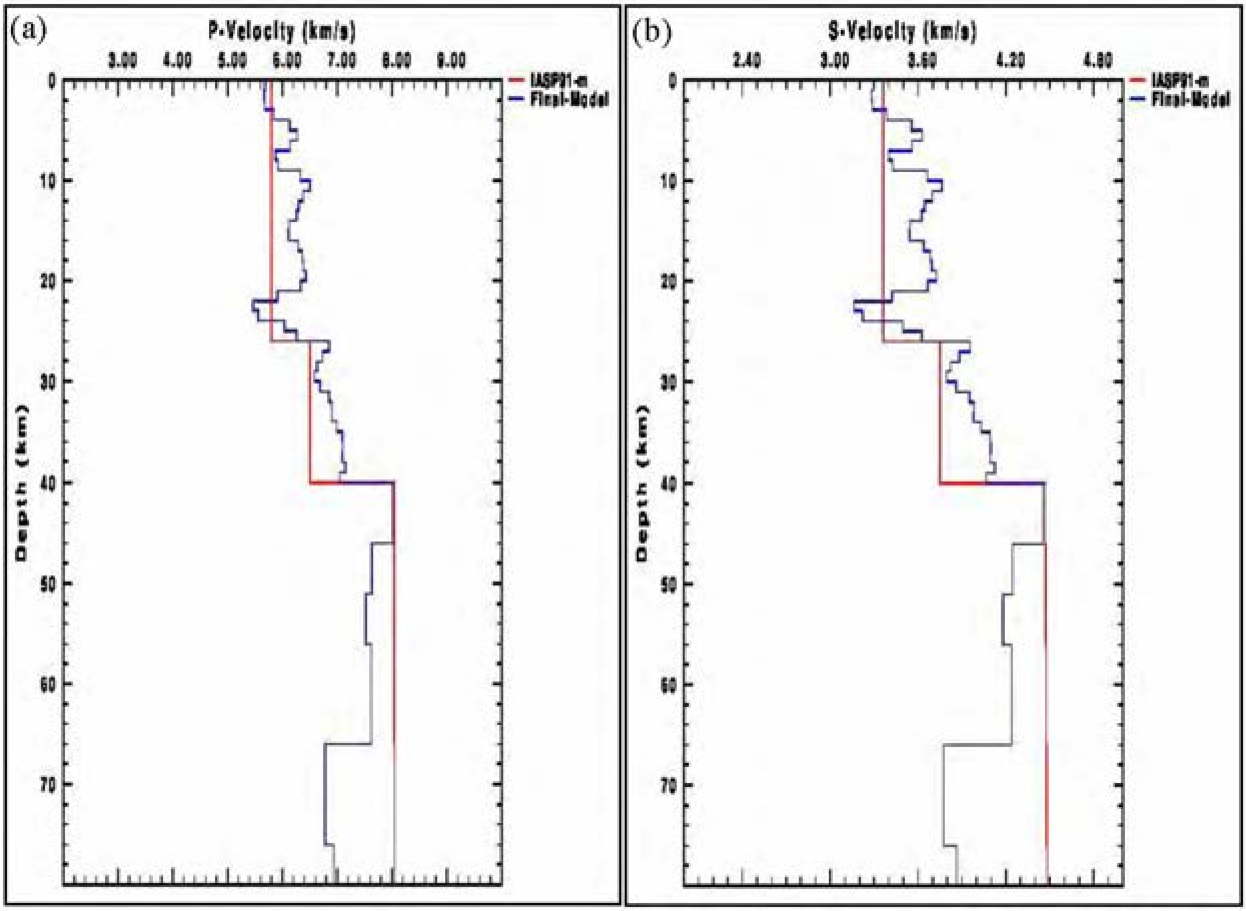

Figure 10: Velocity model after the 2nd and final inversion for (a) P-wave model and (b) S-wave model.

CONCLUSION

The receiver function from tele-seismic earthquakes generated 1-dimensional P-wave and S-wave velocity models in which the crustal properties beneath KKM station are discovered. The explications of these 1-D velocity models show that the Conrad discontinuity is detected at depth 26 km, the Moho boundary is at depth 40 km whereas a low-velocity zone occurred at 66 km depth which indicates the lithosphere-asthenosphere boundary. Hence, the crustal thickness is 40 km consisting of 26 km of the upper crust and 14 km of the lower crust. The velocity input within the crust has a P-velocity range of 5 km/s to 7 km/s and S-velocity range of 3 km/s to 4 km/s. The P-velocity and S-velocity reached 8 km/s and 4.5 km/s as it hits the Moho boundary at 40 km depth beneath the station. These velocity profiles and crustal thickness are proven reliable by cross-checking the results with H-k analysis. Consequently, the very first crustal-mantle model in the Kota Kinabalu region is thus created offering a new subsurface geological perspective within the region.

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Geological interpretation of Spectral Gamma Ray (SGR) of fine clastic rocks from the Nyalau Formation central Sarawak, Malaysia

Walaa Elnasir Ibrahim*, Ahmed Mohamed Ahmed Salim, Chow Weng Sum, Eswaran Padmanabhan

Universiti Teknologi PETRONAS, Department of Geoscience, 32610 Seri Iskandar, Perak Darul Ridzuan, Malaysia
* Corresponding author email address: umshamswalaa@gmail.com

Abstract: The increasing interest for shale gas exploitation as unconventional resources is aided by the new technological advancement that has marked the pathway to explore shale gas for local utilization and national economy in Malaysia. The Nyalau Formation which is an Oligocene - Middle Miocene in age. This article attempts to analyze the depositional environment, Gamma Ray, clay mineralogy and evaluate the relationship between uranium concentration and total organic carbon (TOC) of the Nyalau Formation comprise of shales and mudstones using Spectral Gamma Ray (SGR). The results from SGR indicate to compose principally kaolinite and Smectite, XRD analysis and FESEM reveals the presence of illite. The Th/U ratios vary between 0.57 and 0.85 indicate formation is deposited in a reduced marine environment. Calculated API reveals the ability of the clay minerals to absorb uranium and thorium through cation exchange capacity. The relationship between the cross plot of TOC% / U shows positive correlation.

Keywords: Nyalau Formation, ctral Gamma-Ray log (SGR), clay minerals, organic matter, Shale, Mudstone.

INTRODUCTION

Shale is a fine-grained clastic sedimentary rock (grain size less than 4 microns in diameter) consist of mud and small fragments (silt-sized particles) of other minerals, mainly quartz and calcite (Passey *et al*., 2010) with fissility absent in mudstones (Tucker, 1991; Blatt *et al*., 2006). The increasing interest for shale gas exploitation as unconventional resources aided by new technologies is recently gaining attention in Malaysia to explore shale gas potentials for the national economy and local utilization. There is an emphasis to physically and chemically characterize properties such as TOC%, clay contents and radioactive elements composition and its distribution to understanding their depositional environments by interpretation of varying gamma-ray signatures for non-cored outcrops becomes paramount.

Further studies to evaluate their relationship to critical shale properties such as sorption and adsorption that plays an essential role in shale gas exploration. For decades, reconnaissance investigation in hydrocarbon reservoirs potential entails measuring natural gamma radiation to differentiate between shale and non-shale interludes, while the spectral gamma ray (SGR) procedure is used to subdivide the homogenous marine black shale intervals by fine-scale changes in the distribution of potassium (K), uranium (U), and thorium (Th). This reflect minute mineralogical variances (Fertl & Chilingarian, 1990; McGowan, 2015). Gamma-ray peaks have been a valuable tool used to correlate exposures in outcrop to the subsurface (Aigner *et al*., 1995). Therefore, this necessitates field investigation on outcrops of black shales and mudstones in Nyalau Formation in central Sarawak, Malaysia (Figure 1). Typically, the occurrence of fine-clastic clay-rich rock formation (shale, clay stone, mudstone) indicate high response of gamma-ray while the existence of coarse-grained sandstone and carbonate rock indicate low response of gamma radiation which displays higher water-transmitting capacity (Schon, 2011; Chou *et al*., 2014). The dispersal of U, Th and K mineralas are controlled by the main factors which are the origin of the clastic constituents, chemical and physical stability of these components in the sedimentary environment (Nielsen *et al*., 1987). High gamma-ray activity, high resistivity, and low bulk density is petrophysically described the typical black shale as a sedimentary rock. Moreover, sedimentary rocks like shales show a higher concentration of thorium (Th), uranium (U) and Th/U ratio compare to the igneous rocks (Larsen & Gottfried, 1960). The thorium content of

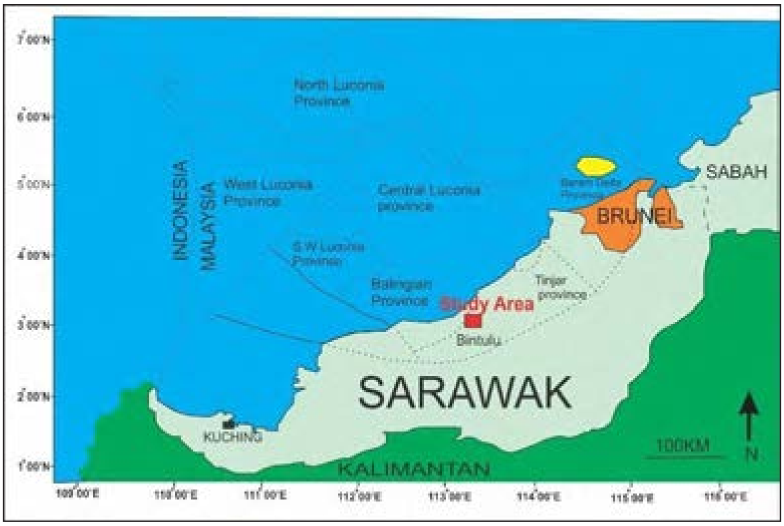

Figure 1: Location map of the study area (Iqbal *et al.*, 2017).

shales differs considerably less than the uranium content (Adams & Weaver, 1958).

Earlier investigation made more assessment of sandstone reservoir textural properties and reservoir interconnectivity of the various sandstone lithofacies in Bintulu and Miri, to develop 2-D intermediate-scale model (Siddiqui *et al*., 2014). Furthermore, partly the Nyalau Formation was considered as a source rock unit, characterized mainly with extensively shale distributed across the Sarawak Basin (Togunwa *et al*., 2015). The textural characteristics of the shallow marine sandstones of the Nyalau Formation is well-exposed from Oligocene–Middle Miocene comprising of minor shale and massive sandstone that were deposited under shallow water marine conditions (Siddiqui *et al*., 2016). Iqbal *et al*. (2017) assessed the Nyalau Formation on the base of measurements for porosity/ permeability and evaluate impact of pore throat size on porosity and permeability in different lithofacies. Moreover, investigation on inorganic and organic of the Paleogene-Neogene coals and related black shales to investigate their origin, depositional environment, and hydrocarbon potential in different formations including the Nyalau Formation (Baioumy *et al*., 2018). Most previous studies focused mainly on reservoir properties with no attempt to explore shale gas potential properties in black shales and mudstones formation.

This article challenges to evaluate clay mineralogical composition to determine depositional environment of the Nyalau Formation black shale and mudstone using Spectral Gamma Ray and the relationship between TOC% and U concentrations in Nyalau Formation onshore, Central Sarawak Basin.

LOCAL GEOLOGY

The Sarawak Basin (Madon, 1999) was considered Late Eocene to Recent age, proposed deposited during Oligocene - Early Miocene times (Wolfenden, 1960). It was also considered as a foreland basin developed from the collision of the West Borneo basement and the Luconia block through Eocene age (Madon *et al*., 2013).

MATERIAL AND METHOD

Onshore samples (9) were taken from three outcrops (Figure 2) from Nyalau Formation, Central Sarawak, Bintulu city. The main specimen used in this study is fine clastic rocks (shale and mudstone) from the Nyalau Formation (Figure 3). Three outcrops of the Nyalau Formation is characterized of mudstones with iron nodules, sandstone and coaly shale (Oligocene–Middle Miocene age), located at coordinates 03° 09' 29.2" N 113° 05' 35.7" E, 03° 09' 24.1" N 113° 05' 51" E and 03° 11' 34.1" N 113° 05' 28.8" E for NY1-A, NY1-B and NY-2, respectively in Bintulu area, Sarawak. Spectral gamma ray (SGR) reading from the outcrops were taken and recorded. The mineralogical analysis was acquired from the X-ray diffraction (XRD) and patterns were generated by Philips-P Analytical X'pert Pro powder diffractometer using Cu Kα radiation. The diffraction data was listed from 3 to 60 2Θ with a step width of 0.02° and a counting time of 4 s per step.

A chip of the samples was coated with a conductive material (gold) and an apparent image of an insulated material is obtained. These coated samples were placed in the chamber, vacated and was scanned using field emission scanning electron microscopy (FESEM). The EDX spectrum points were also carried out by using SEM Petrography Atlas (Welton, 1984). The crushed specimen was weighed and treated with 10% hydrochloric acid (HCl) to remove the inorganic carbon and carbonate minerals. Total organic carbon (TOC)% measurements were obtained using Analytikjena HT 1300 Solids Carbon Analyzer using the direct method proposed by Dow & Pearson, 1975).

Figure 2: Location map of the outcrops in the study area.

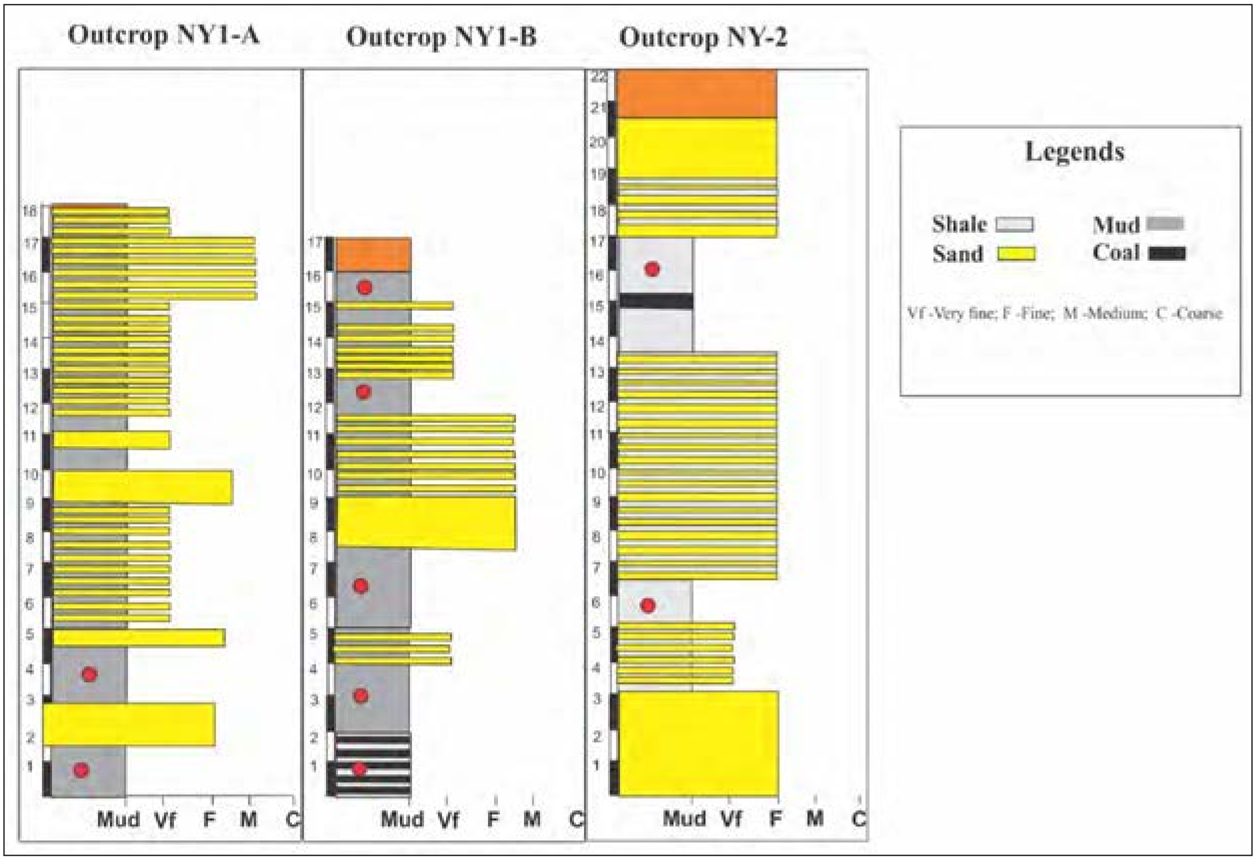

Figure 3: Lithological logs of three outcrops of Nyalau Formation; outcrop NY1-A, outcrop NY1-B and outcrop NY-2 (location in Figure 2) with different packages showing the thickness of sandstone and mudstone within the packages.

RESULTS AND DISCUSSION

Clay mineral identification

Table 1 presents the spectral gamma-ray concentration values from all measured outcrop specimen samples. The concentration composition of K40 varies from 0.56 to 0.98 %, and U 238 range from 12.87 to 18.90 ppm. While Th 232 differs from 9.59 ppm to 12.46 ppm. Thorium (ppm) against potassium (%) plots were used to identify definite clay types (Figure 4), Th/K plots recognized smectite and kaolinite clay minerals with no existence of illite. Uranium high compositions indicate organic-rich shales are potential source beds. These interpretations are general as the identification of clay type using SGR is limited. The minerals of kaolinite, smectite, and illite are observe in most specimen from FESEM analysis (Figure 5). These minerals are confirmed and also revealed occurrence of chlorite (Figure 6A and B) from XRD analysis.

Depositional environment

The Th/U ratios in sedimentary rocks differ from 0.02 to more than 21, and in many continental oxidized deposits values is above 7, while in marine exhibits considerably less than 7 (Adams & Weaver, 1958). Previous researcher proposed that Th/U concentrations ratios serve as critical indicators of sedimentary environments. Koczy (1949) suggested with a little analysis that the Th /U ratio should reduce as the distance from the shore enlarged. Then, the ratios of Th/U differ with the difference in sedimentary depositional environment. The Th/U concentration ratios differs (Table 1) from 0.57 to 0.85, that have indicated Nyalau Formation is deposited in marine and reduced environment.

Gamma ray calculation

The formula adopted from the website https://en.wikipedia.org/wiki/Gamma_ray_logging is used to calculate Gamma Ray in API and the results is presented in Table 2:

$$GR\ API = 8 \times (U)\ ppm + 4 \times (Th)\ ppm + 16 \times (K)$$

The Gamma ray concentration values in shales are more than in other clastic sedimentary rocks, such as sandstone, coal, gypsum, salt and carbonate. This is attributed to occurrence of radioactive element prevalent in the clay content of shales that have the ability to absorb uranium and thorium via cation exchange capacity. Gamma Ray (GR) values in the specimen ranging between 152.76 and 207.12 API is interpreted as high estimated value. This is attributed to occurrence of organic matter which generated a reduction environment that results in precipitation of uranium and subsequent high activity of gamma-ray.

Quantitative relationship between TOC (%) and U concentration

The TOC values range from 0.58 - 1.96 %, indicate that shale and mudstone specimen have fair to good hydrocarbon generative potential, while the coaly shale facies reveals highest value for TOC % (1.96%) as presented in Table 3. This variability is attributed to occurrence of coal within stratigraphic sequence as known to vary from 58.1 to 80.9 wt (Hakimi & Abdullah, 2013) in the study area in the Nyalau Formation.

The plot reveals a good correlation between the TOC determined in laboratory and U concentration from SGR (Figure 7) in different facies type. The occurrence of a high U (ppm) concentration confirms organic matter indicator associated to relatively high organic matter and clay contents present in Nyalau Formation.

CONCLUSION

The representative specimen of the mudstone and black shale from the Nyalau Formation were evaluated to determine their clay minerals composition, depositional environment and also determine relationship between TOC (%) / U concentrations.

A radiometric analysis shows that smectite and kaolinite clay minerals are the dominant obtained from the cross plots of Th against K, revealing occurrence of illite, and validated by FESEM and XRD analysis.

Table 1: Values of potassium, uranium and thorium concentration obtained from Nyalau Formation samples.

Sample No	*Lithology*	*K %*	*U (ppm)*	*Th (ppm)*	*Th/U*
NY1A-1	Massive Mudstone	0.78	17.99	11.31	0.63
NY1A-2	Massive Mudstone	0.57	17.83	10.23	0.57
NY1B-1	Laminated Mudstone	0.73	18.90	11.06	0.59
NY1B-2	Laminated Nodular Mudstone	0.76	18.55	10.54	0.57
NY1B-3	Laminated Nodular Mudstone	0.98	14.84	11.07	0.75
NY1B-4	Laminated Nodular Mudstone	0.66	12.87	09.81	0.76
NY1B-5	Laminated Shale	0.88	16.00	12.11	0.76
NY2-1	Coaly Shale	0.56	14.73	12.46	0.85
NY2-2	Coaly Shale	0.86	14.41	09.59	0.67

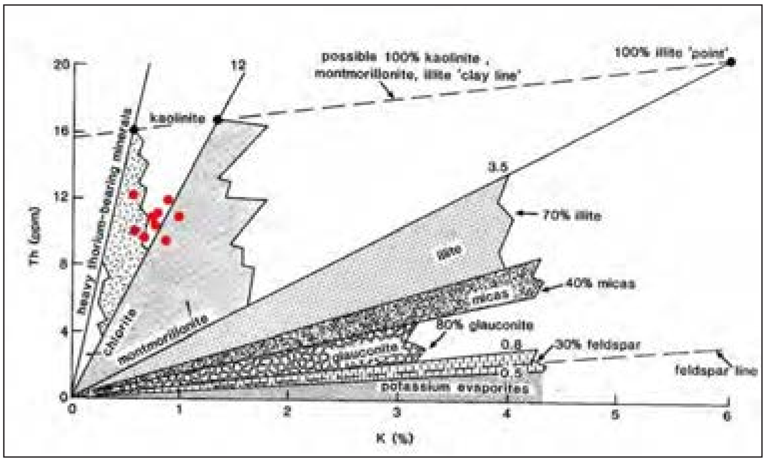

Figure 4: Results of the K % and Th (ppm) cross plot of Spectral Gamma Ray (SGR), using Schlumberger plots (http://www1.uis.no/Fag/Learningspace_kurs/PetBachelor/webpage/tech%5CSchlumberger%20charts%5C07_cp_4-20_4-33.p11.pdf).

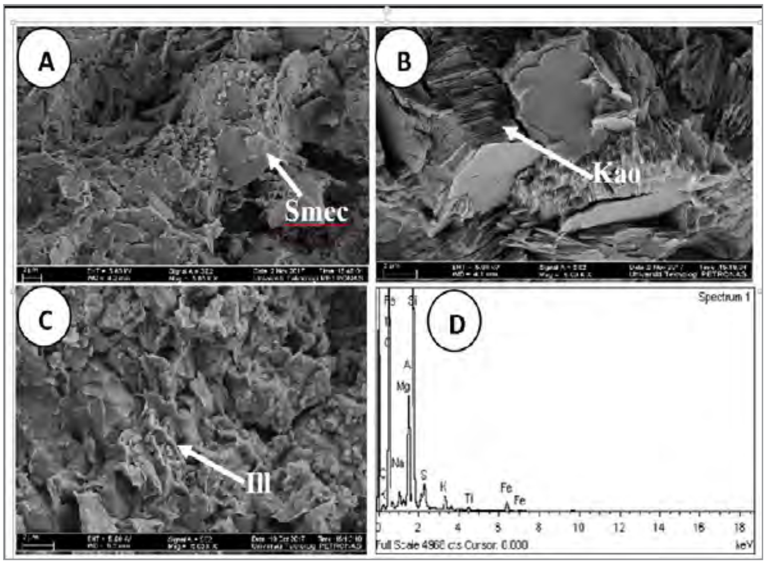

Figure 5: FESEM micrograph showing the clay mineral in the mudstone and shale samples. A) Smec = Smectite mineral with, B) Kaol= Kaolinite and C) Ill= Illite mineral and D) their Dispersive (EDX) Spectrum.

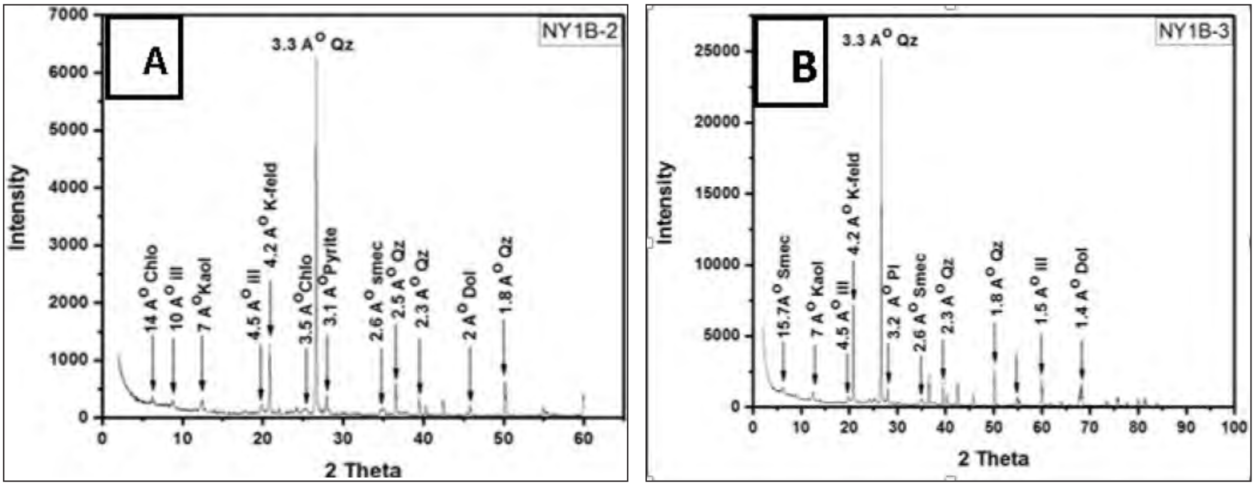

Figure 6: XRD spectrums showing different clay mineral present in the mudstone and shale samples in the Nyalau Formation: A) NY1B-2 and B) NY1B-3 outcrops. Ill= Illite, Kaol= Kaolinite and Smec=Smectite.

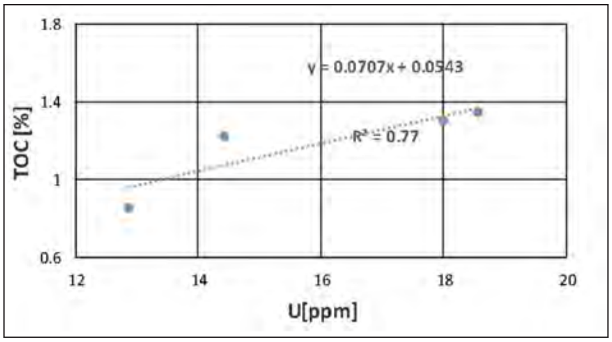

Figure 7. TOC % / U cross plots of mudstone and shale samples in different facies

The indirect application of the Th/U ratios interprets the depositional environment at reduction conditions in marine depositional environment revealing to have ratio value from 0.57 to 0.85.

The high values of the Gamma Ray (GR) range from 152.76 to 207.12 API indicate the ability of clays to absorb uranium and thorium through cation exchange capacity. The cross plots of TOC (%) against U shows considerable positive correlation with the organic matter evolution. This relationship confirmed high presence of U concentration ascribed their relatively higher clay contents and organic matter present in Nyalau Formation

Table 2: Calculated Gamma Ray (GR) values from Nyalau Formation.

Sample No	*Lithology*	*Dose Rate (DR) nGY/h*	*Gamma Ray (GR) API*
NY1A-1	Massive Mudstone	102.11	201.64
NY1A-2	Massive Mudstone	103.78	192.68
NY1B-1	Laminated Mudstone	97.15	207.12
NY1B-2	Laminated Nodular Mudstone	105.27	202.72
NY1B-3	Laminated Nodular Mudstone	84.21	178.68
NY1B-4	Laminated Nodular Mudstone	73.03	152.76
NY1B-5	Laminated Shale	90.78	190.52
NY2-1	Coaly Shale	83.60	176.64
NY2-2	Coaly Shale	81.76	167.4

Table 3: Relationship between the TOC content and the uranium content in the Nyalau Formation.

Sample No	*Lithology*	*U(ppm)*	*TOC%*
NY1A-2	Massive Mudstone	17.99	1.3
NY1B-4	Massive Mudstone	17.83	0.76
NY1B-2	Laminated Mudstone	18.90	0.83
NY1A-1	Laminated Nodular Mudstone Mudstone	18.55	1.35
NY1B-3	Laminated Nodular Mudstone	12.87	0.86
NY1B-5	Laminated Nodular Mudstone	14.84	0.98
NY2-1	Laminated Shale	16.00	0.58
NY1B-1	Coaly Shale	14.73	1.96
NY2-2	Coaly Shale	14.41	1.22

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Application of UAV photogrammetry for quarry monitoring

Sharan Kumar Nagendran[1,2,*], Mohd Ashraf Mohamad Ismail[1]

[1]School of Civil Engineering, Universiti Sains Malaysia,
14300 Nibong Tebal, Pulau Pinang, Malaysia
[2]Centre of Excellence for Engineering & Technology (CREaTE),
Public Works Department (JKR), 78000 Alor Gajah, Melaka, Malaysia
* Corresponding author email address: sharankumar@student.usm.my

Abstract: In quarry production, survey work is necessary to monitor the height of stockpile and quarry's walls to obey the rules and regulation stated by authority. Conventional method of surveying is by ground-based surveying on these sites to measure the X, Y and Z data. Nevertheless, these approaches are very time consuming and a dangerous undertaking for the staff. Advancement of remote sensing specifically unmanned aerial vehicle (UAV) have become an alternative for surveying work. The use of drone for survey that is remotely piloted is able to replace the traditional method of surveying in quarries. This paper describes the application of drone mapping for quarry monitoring and management of stockpile and slope assessment. Quadcopter was used to acquire the aerial images for stockpile and both aerial and side images for slope assessment. The captured images were processed using a photogrammetry software, Agisoft Photoscan to produce the final output consisting of orthophoto, digital surface model, 3D dense point cloud and 3D model. Based on the output, volume, height and area of stockpile computational were made in the photogrammetry software. The slope stability assessment computation was made using facet extraction to identify the major discontinuity sets for rock slope stability analysis. UAV photogrammetry grants precise approach to provide fast data recovery and time saving for mapping a large quarry area.

Keywords: UAV, photogrammetry, quarry, rock slope

INTRODUCTION

Mining activity involves excavating the earth surface for exploring the minerals and it is the oldest economic activity after agriculture (Mondal & Chakravarty, 2013). Mining without appropriate planning and lack of modern technologies usage have adverse impact on the atmosphere especially on dust emission (Nartey *et al*., 2012). Consistently changing nature of quarry landscape implies that a regular monitoring of the whole area helps in effective management of such activities for example re-routing roads, position of heavy machinery, location of different type of stockpile and surveying of blast material and stock piles. Successful organization of a quarry needs quick and precise information where the results must conform to a specific legislation. Quarry data collection consists of constant surveying on the changing shape of the quarry and its elements such as berms, bench heights, slopes, and reliable computation of the volume of the extracted mass (Raeva *et al*., 2016).

The utilization of innovative technology such as UAV will be very important to learn and monitor mining and quarry areas especially in risk assessment and management. The use of UAV will enable mapping of the entire quarry in a fast way to improve the overall project management. Additionally, it will be very beneficial in measuring stockpile volume, height, diameter and density to assist in stock calculation, arrangement of deliveries and to support robbery prevention. Conventional surveying method of using total stations and traditional global positioning system (GPS) are time consuming, requiring many readings on one stockpile for accurate measurement of the stockpile.

Although conventional method has been practiced in characterizing the rock masses in quarry, the use of UAV photogrammetry method is reliable and effective (Salvini *et al*., 2017) (González-Aguilera *et al*., 2012). Application of UAV photogrammetry in many engineering applications signifies it as a suitable and effective solution considering the accessibility and lower investment cost of using UAV (González-Aguilera *et al*., 2012). Photogrammetric survey is able to produce digital orthophoto, digital surface model (DSM) and 3D dense point cloud with the aid of structure from motion (SfM) software (Esposito *et al*., 2017).

With the development of UAV, geologists are able to document the normally accessible elements of geological outcrops or the dangerous parts of the rock mass. Images from the digital camera mounted on a UAV is able to capture the geological outcrops, big areas and to attain inaccessible valuable missing data (Blistan *et al*., 2016). This method can be used to overcome the problem of unseen areas and to acquire detailed information on any feature. 3D point clouds obtained from image processing have been used to rebuild the quarry geometry and then discontinuities were then mapped deterministically in detail (Salvini *et al*., 2017).

Analysis of UAV images by SfM approach establishes a reliable and validated tool for surveyors who are concerned with high-resolution reconstruction and monitoring of quarries. Photogrammetry output provide a useful tool for management of the environmental risk of dangerous and inaccessible areas, and they enhance the geotechnical interpretation for engineers to make decision (Rossi *et al*., 2017). This paper presents the method to monitory and manage quarrying work effectively through photogrammetry output with minimal cost.

STUDY AREA

This study was conducted in Kuad Quarry at Kubang Semang, Pulau Pinang which serves as a nonmetallic mineral mining and quarrying site. The site is located at coordinate of 100.47 north and 5.41 south. The bedrock of the study area is acid intrusive which is the igneous rock. Figure 1 below shows the location of study area and its geology.

METHODOLOGY

The main elements in this study is to carry out the UAV flight mission to obtain aerial imageries for quarry monitoring and assessment. Mission planning were done using DJI Ground Station Pro application to input all the acquisition parameter. Mapping area boundary was marked on an interactive map, including flying height of the UAV to capture images, the course angle of pathway and the percentage of front and side photos overlapped. The percentage of overlapping photos is critical in producing an accurate sparse cloud of the study area. Front and side images overlapping ratio is 80% and 70% respectively. Waypoints were generated after all the settings were set, showing the global position, distance covered, flying height above ground, number of images that will be captured, the estimated battery usage and duration of the flying mission.

Agisoft PhotoScan Professional version 1.4.3 was used to process images through photogrammetric

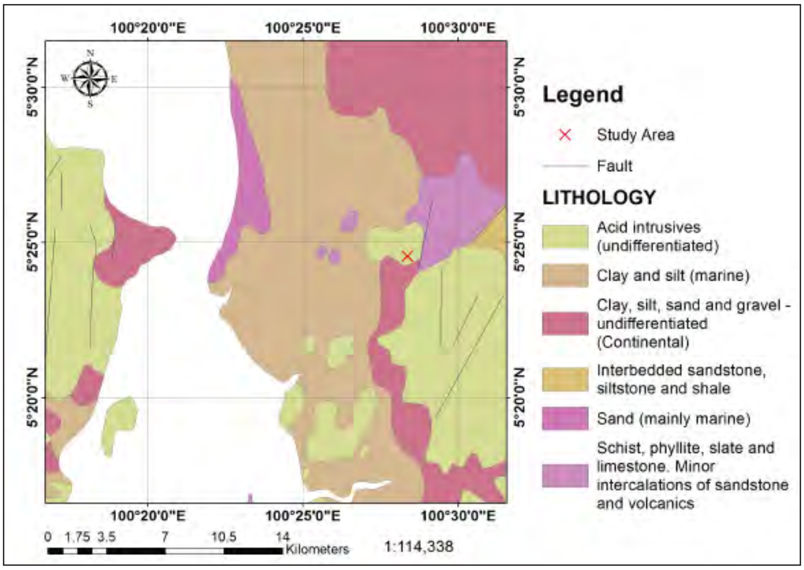

Figure 1: Location and geology map of study area.

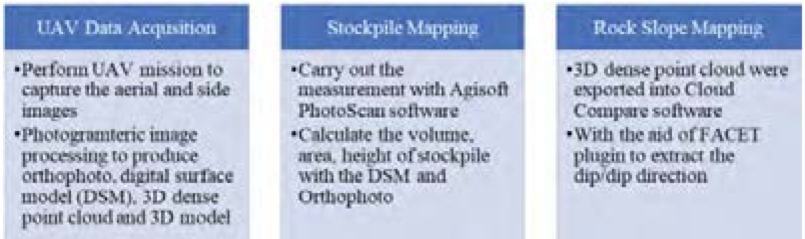

Figure 2: Summary of methodology.

technique. All images were aligned together accordingly before generation of dense point loud and model through interpolation and aerial triangulation process. The structure from motion (SfM) algorithms in the software will extract and match the same features appeared in the images automatically known as tie points and followed by bundle block adjustment. Sparse clouds will be produced as an output of the process. Then, dense geometry was ready to be constructed with its accuracy set to high level to obtain a denser point cloud. Construction of 3D textured model, Digital Surface Model (DSM) and orthophoto were then processed from the dense point clouds.

Stockpile assessment was made through Agisoft PhotoScan for calculation of area, volume, and height of stockpile. Output from the photogrammetric process then is exported into CloudCompare a free software to perform facet extraction for rock slope assessment with the value of mean dip/dip direction. After the meshes or facets are extracted, they can be classified by orientation (dip/dip direction) into single planes and plane families. Facets is then filtered based on their orientation to identify the major discontinuity sets. A stereogram can be produced based on the major discontinuity sets which can be useful for rock slope stability analysis. Query can be done on the stereogram with the outcrop portion being selected. This data can be very useful to check the stability of the rock slope without performing the traditional geological mapping work on the discontinuity.

RESULTS AND DISCUSSION

Stock pile mapping

PhotoScan is able to provide high accuracy polygon models and DSM which guarantees accurate area and volume measurements including length, width and height. Figure 4 below shows the photogrammetric output for stockpile data processing which is the orthophoto and DSM.

The 3D model can be utilized to compute the correct volume of stockpile at site, regardless of any kind of shape as shown in Figure 5. Aerial data and successive analysis can be simply shared to the stakeholders, permitting clients to keep track of their contracted stockpiles materials. It allows the mining engineer to keep track of their large trucks, excavators, and other assets, to ensure accountability and cost reduction in machinery. Traditional method of stockpile survey is to walk to each pile to take manual reading which requires workforce and time consuming. With drone survey, stockpile measurement is able to be completed in hours not days.

Rock slope mapping

Rock slope mapping using UAV is also very important to analyze the stability of slope after mining work in a fast manner. Figure 6 below depicted the outcome of rock slope mapping. Based on the 3D dense cloud, automatically extract planar facets using the FACET plugin in CloudCompare software as shown in Figure 7. Best

Figure 3: Flowchart of geological planes extraction in CloudCompare.

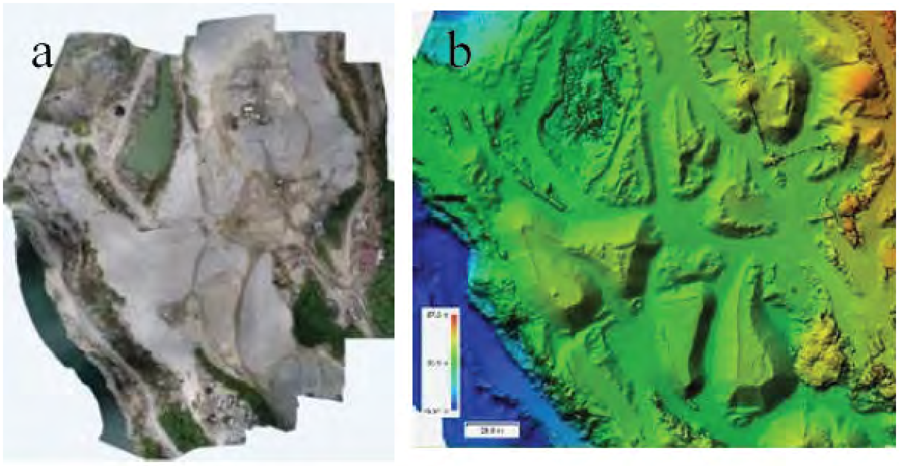

Figure 4: (a) Orthophoto (b) Digital Surface model for stockpile mapping.

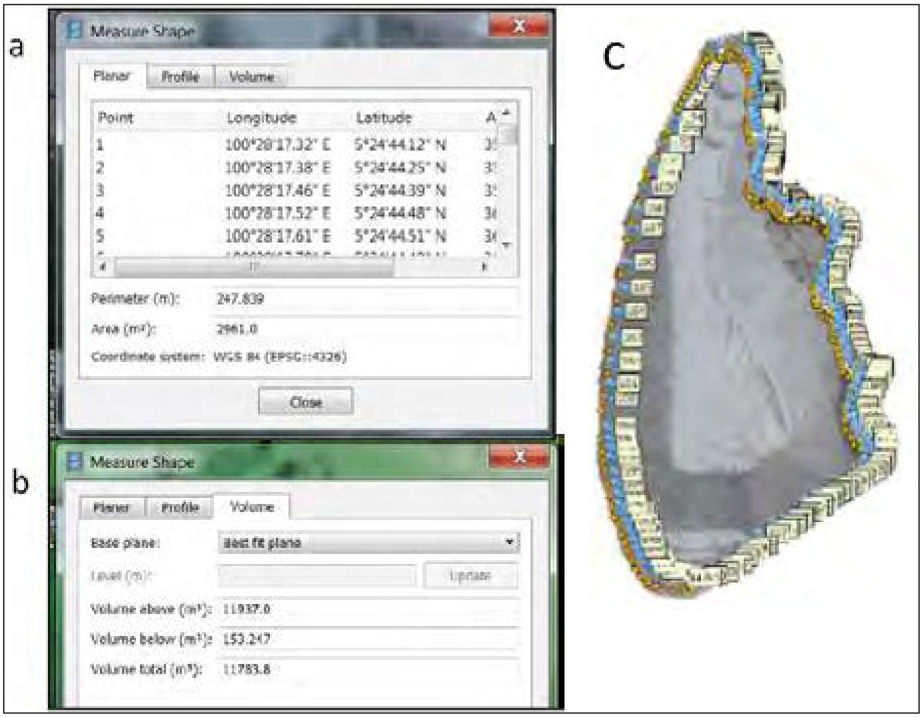

Figure 5: (a) Area and perimeter (b) Volume (c) Stockpile used for the measurement.

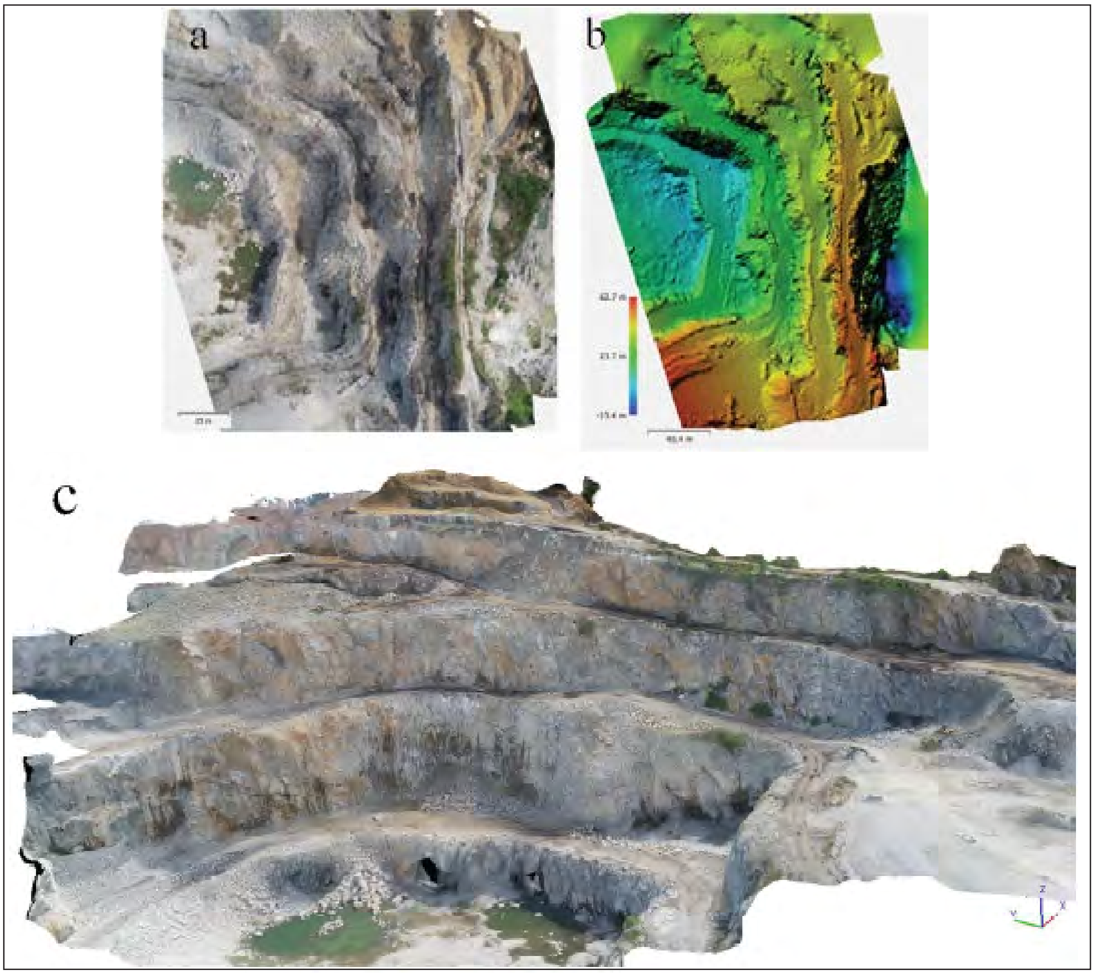

Figure 6: (a) Orthophoto (b) DSM (c) 3D Model of rock slope.

features of FACETS is having the capability to discover planar objects but also 3D points with the stereogram tool.

Stereograms diagram were generated based on the major geological planes which gives out the mean value of dip/dip direction. This value is significant to assess the rock slope in the preliminary stages before using a detailed slope stability software. Further analysis can be made based on the 3D model exported from the photogrammetric process into the slope stability software which represent the real site condition. For the entire rock slope, the mean dip/dip direction is 035°/186°.

Rock quarrying area is usually prone with steep slopes, unstable rock faces and lots of heavy machinery, it can be hazardous space to work. UAV mapping ability to improve worker safety by eliminating the necessity to have men on the site and around the operating space especially near the stockpiles and equipment. Collecting ground control points (GCP) undeniably improve the accuracy of volumetric measurements. GCPs must be placed or marked permanently at the working space for repeated use. However, for this paper integration of GCP in UAV mapping is excluded. The overall accuracy of the UAV mapping without GCP implementation can be categorized as relative accuracy.

CONCLUSION

UAV is becoming very common in industry mainly civil engineering and mining. UAV photogrammetric application can be useful in quarrying work because quarries landscape is changing from time to time. Therefore, quarry site must be scanned frequently and efficiently for planning, management and reporting purposes by the quarry operation team. Output from the photogrammetric process can be used to plan operations such as the reposition the equipment and machinery, stockpile inspection and redirecting the

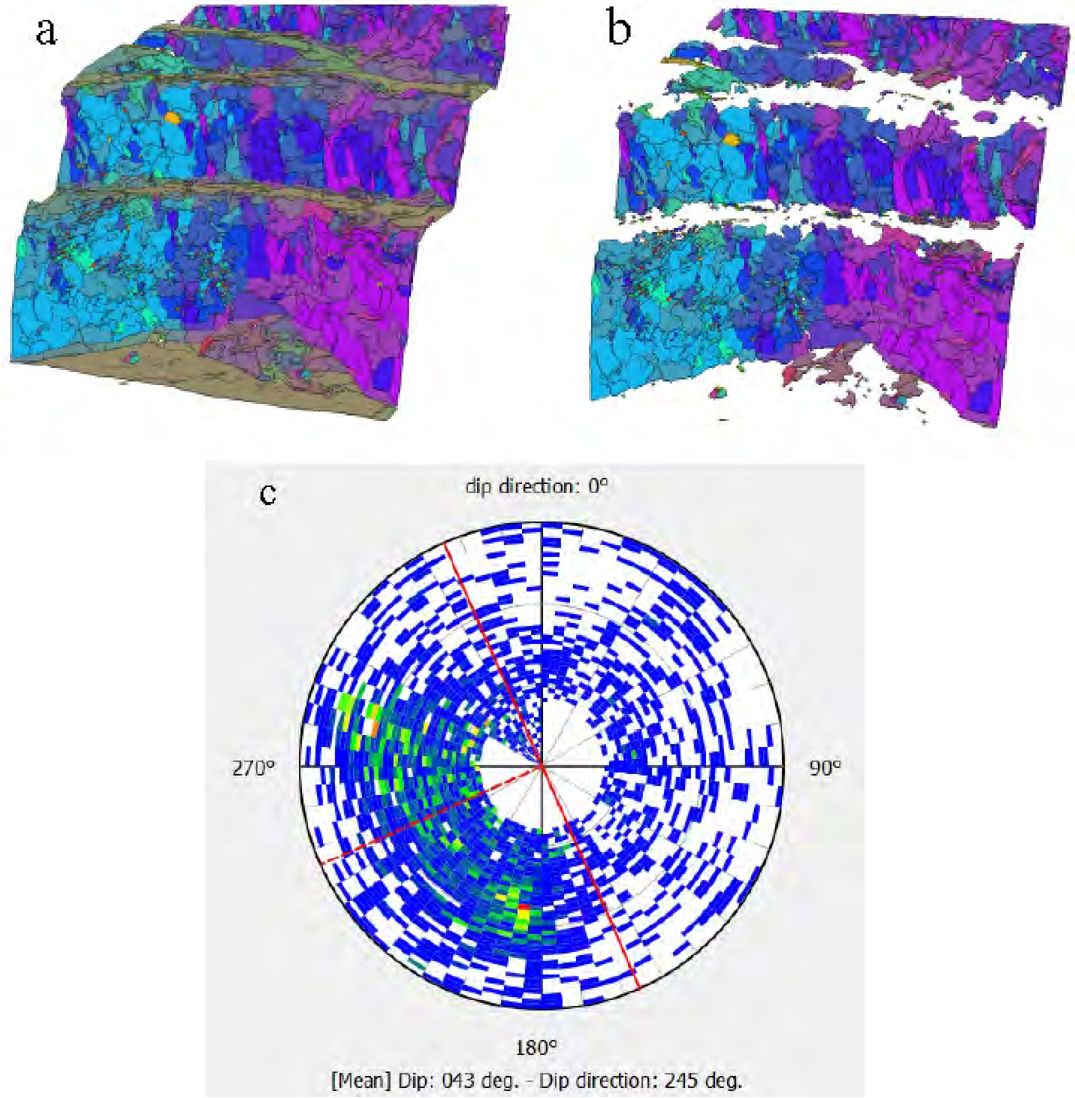

Figure 7: (a) Facets extracted (b) Filtered facet (c) Stereogram.

access roads for transferring the quarry product. The use of photogrammetric output and FACET extraction in stockpile and rock slope assessment is able to provide useful data to make preliminary decision at the working space in short period. Besides, UAV data can be very useful to give an overall view of the quarry site, projection for future changes and to identify anomaly.

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The effect of land reclamation on water clarity in Tanjung Tokong using remote sensing

Nurulamani Rosman, Aisah Taufik, Ismail Ahmad Abir*

School of Physics, Universiti Sains Malaysia, 11800 Gelugor, Pulau Pinang, Malaysia
* Corresponding author email address: iahmadabir@usm.my

Abstract: Reclamation land project in Tanjung Tokong, Penang is one of the sign of the rapid urbanization of Penang island due to the increase in population and a need for land. However, recent increase in public awareness of the negative effects of land reclamation projects on the local fishing community and the marine habitats has made it important to study the changes in the coastal water quality that relates to these projects. Therefore, this study is an initial attempt to measure water quality, mainly water clarity, using cost-effective satellite remote sensing images. Secchi disk depth measurements is collected around the Tanjung Tokong reclaimed land at the same time as the Landsat 8 image of Penang island is recorded. The Secchi disk measurements are compared and correlated with the reflectance data of the Landsat image resulting in a correlation equation. Based on the equation, water clarity is then estimated for previous Landsat images of Penang. Finally, Secchi disk depth measurements is also collected for the west coast of Penang island for comparison purposes. Our results show that the NIR (Near-infrared) band is the most sensitive for water clarity estimation. Furthermore, the water is generally clearer in the area to the west of Penang island where there are no land reclamation projects. However, there are other environmental factors which were not take into account, such as tidal changes, that will also affect water clarity.

Keywords: Water clarity, remote sensing, Secchi depth, landsat

INTRODUCTION

Penang Island is one of the fastest-growing and most densely populated places in Malaysia with a population of 752,800 (Department of Statistics Malaysia, 2015) and a density of 1663/km^2 (Penang Institute, 2016). The population on the 299 km^2-island has increased by more than 40% since 1970 (Department of Statistics Malaysia, 2015) and is projected to rise exponentially over the next 15 years (Penang Transport Master Plan Study, 2013). Due to the rapid population growth and the simultaneous increase in urbanization, land reclamation has been extended to the construction of man-made islands (artificial islands) (Chee *et al.*, 2017). Land reclamation in Penang began in the early 1800s (City Council of Georgetown,1966) during the British administration, but recent large-scale coastal development projects have contributed to the alteration of the coastline of Penang to make way for transportation and infrastructure (City Council of Georgetown,1966; Khoo & Wade, 2003).

Land reclamation is a process of creating new land in water bodies either along coastal areas or in the form of new islands (man-made island). Coastal reclamation has become a serious development option in Malaysia (Ghazali, 2006). Reclamation land in coastal areas may have a significant effect on the ocean water. The main issue is water pollution and this may affect marine life and also human. The recent public protest regarding the newly planned reclamation projects in south Penang Island shows that the public is becoming more aware of their negative impacts, especially to the environment (FMT News, 2019). The fisherman community to the north of Penang Island (Tanjung Tokong) has been complaining about the significant loss of fish and other marine life during the reclamation project. Due to the public and environmental concerns, this work was conducted as an initial attempt to monitor the quality of coastal water of Penang Island in relation to reclamation projects. Hence, it is important to monitor water clarity from time to time. Water clarity defined as a physical characteristic of how clear or transparent the water. Water clarity has been measured in standing water bodies using a Secchi disc. Secchi disk is the simplest and one of the most effective tools for estimating water column productivity. It is also a measurement of water clarity where water transparency directly affects the amount of light penetration into water column.

However, field work is costly and time consuming. Therefore, this work focus on utilizing remote sensing to estimate the water clarity based on the reflectance data. Reflectance values that we obtained from processed

Landsat data were used to correlate with Secchi depth (SD) measurements. Reflectance remote sensing (Rrs) can be defined as the ratio of water leaving radiance to the total downwelling irradiance just above water (Pahlevan *et al.*, 2017). SD measurements were collected on the same date as the Landsat 8 image so that we can correlate based on the linear regression approach.

The study area chosen was Tanjung Tokong, Penang (05° 26' 51" N, 100° 18' 24" E). The area is located within the north-west coast of Peninsular Malaysia which is in the northeast of Penang Island (Figure 1). The Tanjung Tokong Beach is located west of Tanjung Tokong headland. It is categorized as a moderately exposed sandy beach with medium to fine sand. Shell debris can be found easily on the foreshore of this beach. The water is often turbid indicating a relatively high content of suspended sediments (Ramly, 2008). In addition, to compare the measurements of ground-based data with Tanjung Tokong, a different study area was chosen, which is the Penang National Park (05° 27' 42" N, 100° 11' 24" E). This area is located on the north-western tip of Penang (Figure 1). The Penang National Park is the only considerable natural forested areas left on Penang Island. It is considered one of the protected areas under the management of the Department of Wildlife and National Parks (DWNP) (Kaffashi *et al.*, 2015).

DATA AND METHODS

Ground data acquisition

Secchi depth (SD) measurements were collected and correlated with satellite data. The correlation between actual Secchi depth and satellite data will be used to estimate the Secchi depth from archive satellite images. 25 SD readings were collected surrounding the land reclamation project which covers 1km per square with the same date as Landsat-8 image (Figure 2). The data was gathered on 20th December 2017.

Satellite data acquisition

Landsat 8 imagery was downloaded from Earth Explorer - United States Geological Survey (https://earthexplorer.usgs.gov/) with Path Type WRS 128 and Row 56. The date of acquisition of the imagery is 20th December 2017, which covers the area of northeast of Tanjung Tokong coastal area. The projection of the imagery is UTM WGS84 Zone 47 and its spatial resolution is 30 m x 30 m.

It was important to acquire Landsat image that was recorded at the same time as field data collection. This will result in better correlation. The image was downloaded in a package containing a total of 11 spectral bands in GeoTiff format, 1 quality assessment band and 1 metadata file in ASCII format. However, only the visible-near infrared bands, which are bands 1-7, were used for analysis.

Satellite and ground data processing

For the processing of the data, Envi® 5.3 and ArcMap 10 were used for image analysis. The techniques involved are:

1. Landsat 8 multispectral image data underwent radiometric calibration to provide calibration

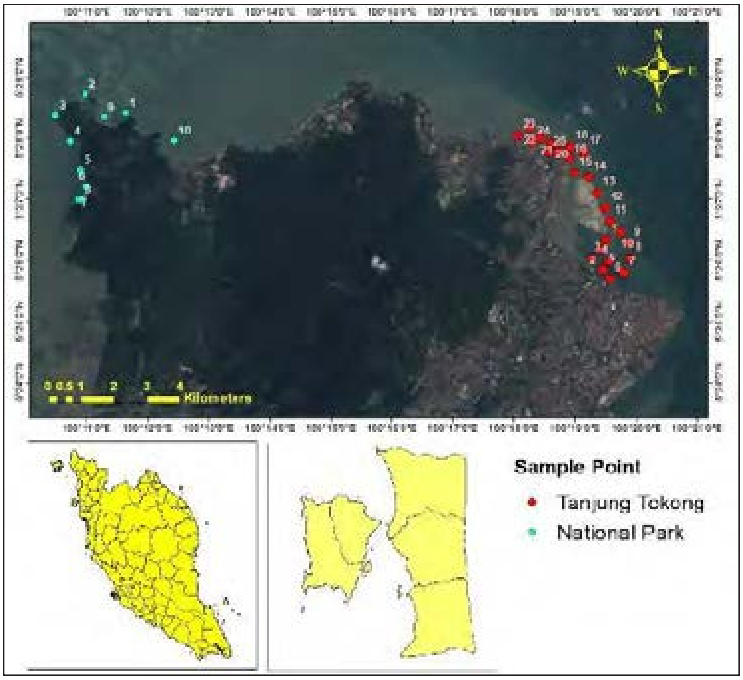


Figure 1: Study area around Tanjung Tokong (reclamation land) and Penang National Park (control area) which are located in Penang, Malaysia.

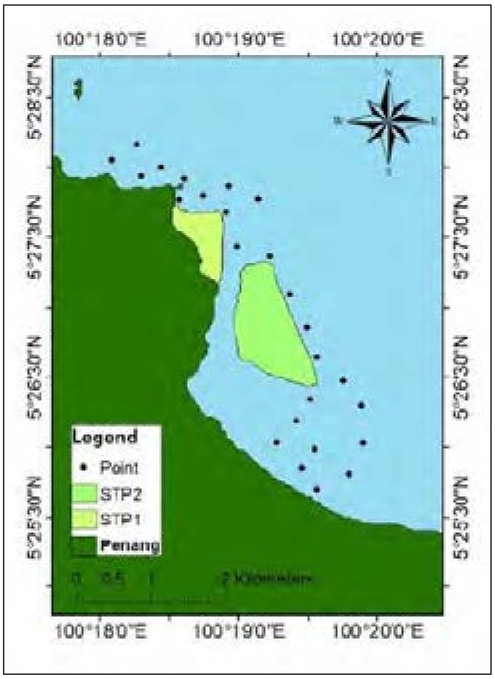


Figure 2: The dot points show the stations of collected data.

coefficients to convert from digital numbers (DNs) to Top of Atmosphere (TOA) Reflectance.

2. Dark subtraction was applied to remove the effect of atmospheric scattering from an image by subtracting a pixel value that represents a background signature from each band.
3. From the imageries, the digital number of reflectance values for every band on a specific date and location was extracted using ArcMap 10.

The data was added into ArcMap which were then processed by using interpolation tools named IDW (inverse distance weighting) to produce Secchi depth distribution map of the study area.

In order to test the relationships between the Secchi disk depth within the study area and the reflectance from Landsat 8 image, linear regression was used. This is done through Microsoft Excel software.

Estimation of Secchi depth for archived satellite images by using selected model

After the linear regression has been run, we used the equation with the highest R squared to estimate the Secchi depth for archived Landsat 8 images. A total of six Landsat 8 images were downloaded. Images in the best condition were viewed and selected with less cloud cover. Moreover, we selected images from before and after the reclamation project for comparison purposes.

The calculation was done by using ENVI 5.4 software by inputting the equation in the band math. Then the value was extracted by using ArcGIS software. Steps for this data processing are shown in Figure 4.

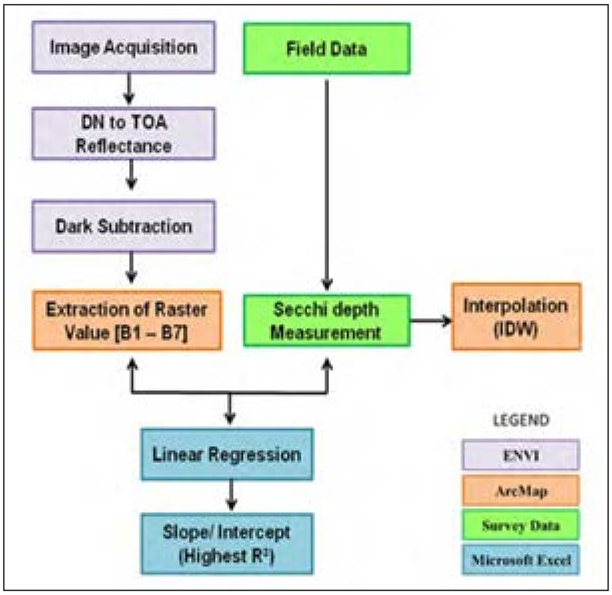


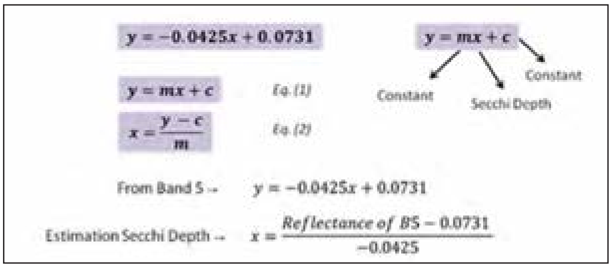
Figure 3: The overview flowchart of overall methodology shows the flow diagram from acquisition of satellite image until the estimation of Secchi depth.

RESULTS AND DISCUSSION

Secchi depth distribution in Tanjung Tokong coastal area

The distribution shows different result from the hypothesis where the water columns located close to the land reclamation project are supposed to be more turbid compare to undisturbed coastal area. However, there are a lot of environmental factors such as waves, tide and current cycles that were needed to be considered that could affect the Secchi disk readings. All the factor mentioned are categorized as uncontrollable factors and will introduce error in the interpretation of factors that could affect the Secchi measurements.

To better understand the effect of reclamation land, comparison of data with controlled area (Penang National Park) was done using Secchi depth measurements. There is a slight contrast of SD measurement between land reclamation area and control area. In general, all ten sample sites of the coast of Penang National Park show increase in SD readings (Figures 5 and 6). This is an indication of higher water clarity. The Secchi depth readings on this particular area reached ~2 m of water column depth. High Secchi depths are associated with high water clarity and low turbidity. In contrast, the Secchi depth for the Tanjung Tokong area is only up to ~1 meter in depth.



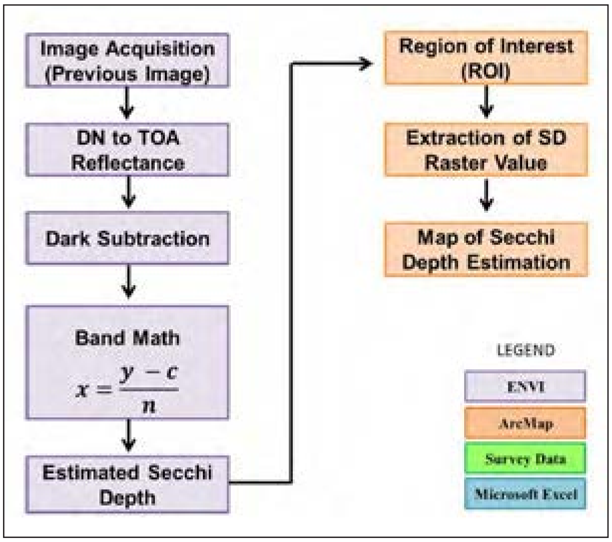


Figure 4: Flow chart of process to determine the estimate value of Secchi depth.

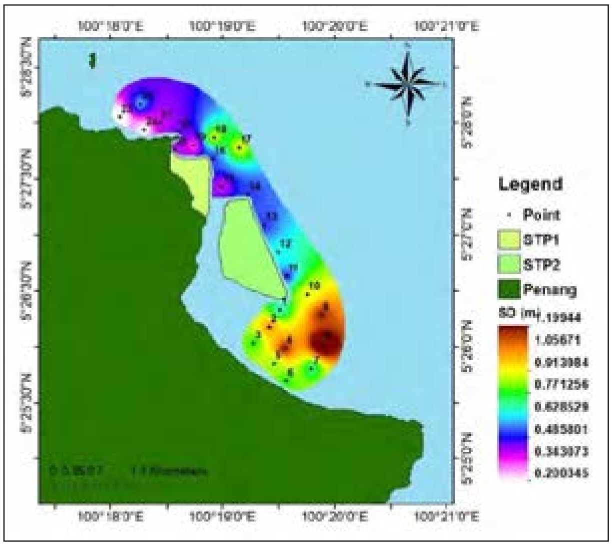


Figure 5: Distribution of Secchi depth measurements of Tanjung Tokong coastal area.

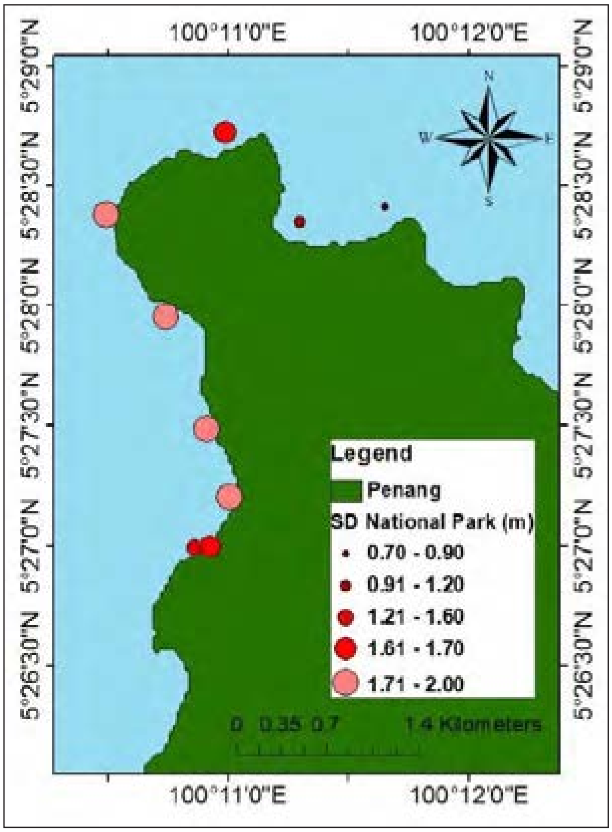


Figure 6: Distribution of Secchi depth measurements in Penang National Park.

Correlation between Secchi depth and reflectance value

Based on the Table 1, we can clearly see the differences of the coefficient of determination between all bands. Band 5 shows the highest coefficient of determination (R^2=0.7051)which shows that the model

Table 1: Summary of the performance statistics linear regression using different band.

	Regression Equation Coefficients	R^2
SD vs Reflectance-B1	y = -0.0226x + 0.1776	R^2 = 0.557
SD vs Reflectance-B2	y = -0.0289x + 0.1711	R^2 = 0.5351
SD vs Reflectance-B3	y = -0.0398x + 0.1663	R^2 = 0.558
SD vs Reflectance-B4	y = -0.0711x + 0.1495	R^2 = 0.6533
SD vs Reflectance-B5	y = -0.0425x + 0.0731	R^2 = 0.7051
SD vs Reflectance-B6	y = -0.0123x + 0.0264	R^2 = 0.5726
SD vs Reflectance-B7	y = -0.01x + 0.0194	R^2 = 0.5643

equation fits the data relatively well when compared to other bands (Figure 7). It shows that an increase the values of Secchi depth correlates with the decrease in the reflectance values. Others band also shows correlation with the Secchi depth readings: Band 1(R^2 = 0.557), Band 2(R^2 = 0.5351), Band 3 (R^2 = 0.558), Band 4 (R^2 = 0.6533) and Band 6 (R^2 = 0.5726).

One has to consider that in conditions where there's an increase of electromagnetic wavelength, water has a lower reflectance. In the NIR (Near-Infrared) (0.845 – 0.885 µm) range, water has a strong absorption capacity and produces less remote sensing reflectance. In the use of NIR, the latter relationship require an assumption of equivalent spectral dependency for back scattering and scattering. As the electromagnetic wave radiation of NIR travel into the water, it will be absorbed. For such area which is turbid (lower Secchi depth), it consist of suspended particle, thus suspended matter in water causes scattering of the radiation.

Estimation of Secchi depth

The linear regression equation was applied to estimate the water clarity parameter based on band 5 (Near-Infrared) of Landsat 8 image. The use of consistent band helps us make the analysis of different images comparable and is an important step towards standardizing produced maps.

Figure 8 represents contour maps for predicted Secchi depth model at Tanjung Tokong near the reclamation land (on 23rd November 2013, 31st December 2015, 20th March 2016, 17th December 2016, 24th April 2017 and 11th June 2017). From the maps, the changes of historical coastal water up to the extent of reclamation land can be seen. It

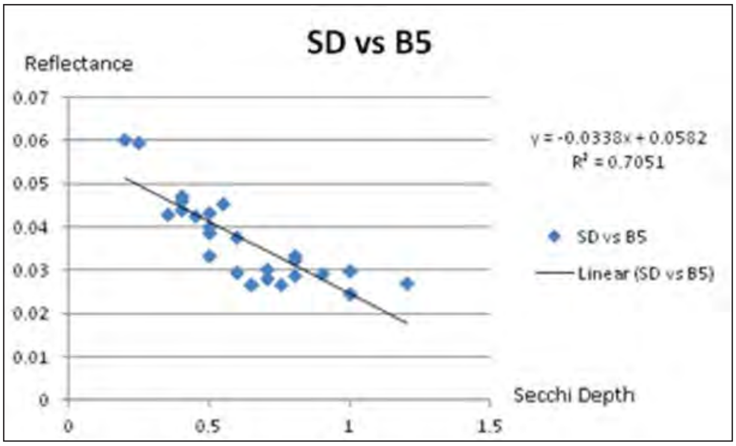


Figure 7: Correlation between Band 5 and Secchi depth.

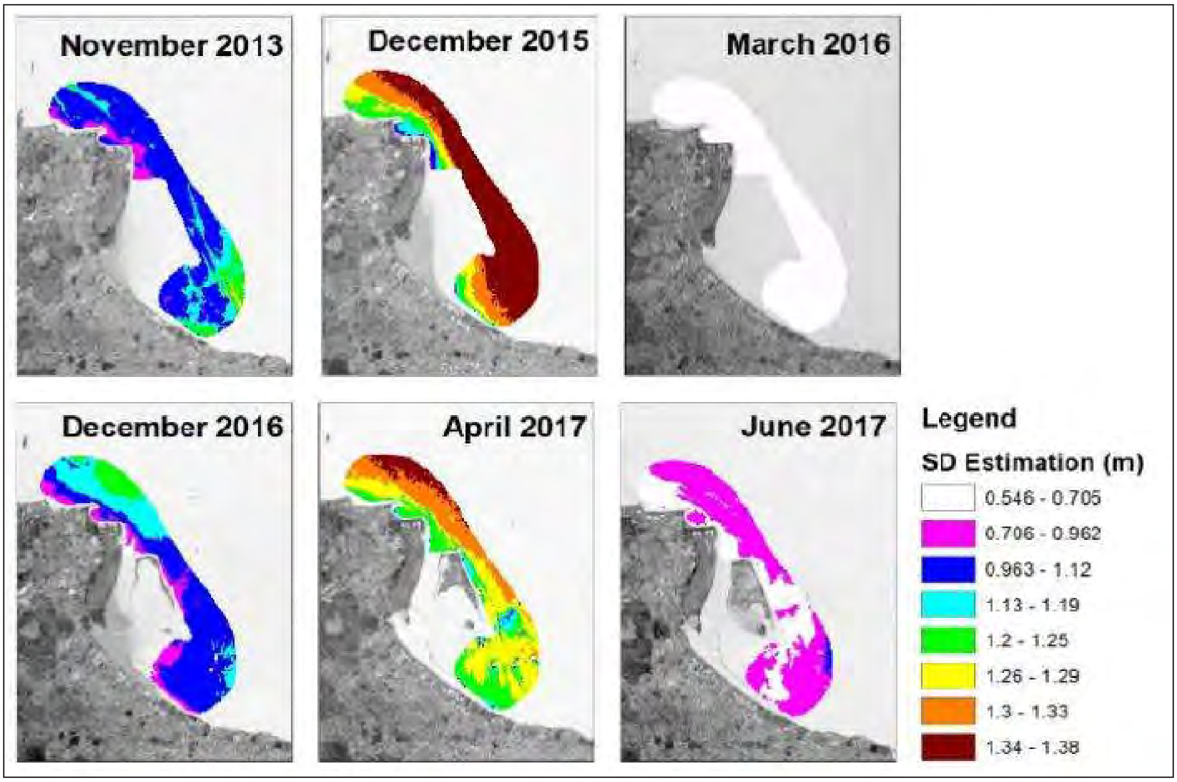


Figure 8: Maps show Secchi depth estimation derived from Landsat 8 imageries based on region of interest from November 2013 to June 2017.

is observed that the levels of Secchi depth varied and are unevenly distributed. It indicates that the use of Landsat 8 image to measure water clarity in coastal areas is sensitive, especially to weather and other environmental factors.

Interesting observations from the map pattern show that the predicted SD significantly gets lower throughout the year, as indication of poor water clarity. This lower SD coincides with increased turbidity observed in those areas. Undoubtedly, negative effects on the island's natural coastal habitats and water will be inevitable.

CONCLUSION

In conclusion, it was noticeable that land reclamation in Tanjung Tokong affects the water clarity in terms of light penetration. It showed that the water become turbid. The best regression is found from the high correlation value between reflectance of NIR band and Secchi Depth.

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Evaluation of tunnel interaction in Kenny Hill Formation using Finite Element Modelling

Darvintharen Govindasamy[1], Mohd Ashraf Mohamad Ismail[1,*], Mohd Faiz Mohammad Zaki[1,2]

[1]School of Civil Engineering, Universiti Sains Malaysia, 14300 Nibong Tebal, Pulau Pinang, Malaysia
[2]School of Environmental Engineering, Universiti Malaysia Perlis, Perlis Malaysia, Malaysia
* Corresponding author email address: ceashraf@usm.my

Abstract: The number of town population growth is the reason for the expansion of transportation and infra-structures in metropolitan cities. Due to that urban tunnelling has turned out to be common in most area. Considering the environmental impacts, going underground become a feasible choice for the development of transportation. But, when dealing with urban tunnelling, one always meet with complex mechanism due to soil interaction between ground and tunnels. Tunnelling problem must be considered as a three-dimensional problem. However, we can simulate the three-dimensional plane problem into a two-dimensional plane problem by considering certain assumption which governs the missing dimension. This paper is to show the simplified method for ground settlement prediction of tunnelling excavation using the PLAXIS 2D software. The two simplified methods are lining contraction and stress reduction method. The comparison between these two methods is described in this paper in terms of contraction ratio and unloading factor which can be used for tunnelling problems. This study was done in the Kuala Lumpur Kenny Hill Formation basically based on geotechnical data of Klang Valley Mass Rapid Transit (KVMRT) system. Hardening soil model is choosen as the constitutive model for this analysis because of its ability to represent the actual soil behaviour compared to Mohr Coulomb Model. The effectiveness of simulation using these two methods was verified with the monitored ground movement data. A relationship between these two methods was formed as the outcome of the study.

Keywords: Lining contraction, stress reduction, Kenny Hill Formation, hardening soil model, tunnelling

INTRODUCTION

Development of roadways and highways are no longer adequate in recent time because of populace and cities growth. To solve this issue urban tunnelling concept come into practice in most area. In real case, tunnelling construction involves a three-dimensional concept. Due to time consumption of three-dimensional analyses, engineers prefer two-dimensional in practice. Moreover, three-dimensional analyses are not suitable to apply for a large tunnel project that involves several kilometers of excavations and various cross sections (Moller & Vermeer, 2006). The geology of Kuala Lumpur and Klang Valley is mainly Kuala Lumpur Limestone and Kenny Hill Formation. This study only concentrates on the Kenny Hill Formation. The Kenny Hill Formation is a metasedimentary rock which consist of phyllites, quartzite and other soil particles. One of the developments in Kuala Lumpur and the area surrounding it is the construction of the Klang Valley Mass Rapid Transit (KVMRT) system which started construction in 2012. The reason for the project was to improve public transportation facilities and reduce traffic congestion problem in the populated area. This project includes twin tunnel excavations, deep excavations and geotechnical works.

These days, Finite Element Method (FEM) comes to mind when one needs to deal with tunnel excavation problems. This method is a famous and useful device to simulate tunnel construction works. Many geotechnical software developers apply FEM in their computational tool to solve geotechnical problems. However, the use of FEM in settlement prediction is still not that much accurate because of many factors such as simplified geometry and boundary condition, mesh generation, initial input of ground data and the type of constitutive model chosen for the analysis (Likitlersuang *et al*., 2014). To understand the behaviour of the soil, researchers developed soil constitutive model. A soil constitutive model is a mathematical relationship that represents the soil interaction and its behaviour. The simple and widely used soil constitutive model is the

Mohr-Coulomb Model which based on linear elastic and perfectly plastic concept. Nevertheless, the soil interaction is much more complex which cannot be demonstrated by the Mohr-Coulomb Model. This is because, at a different stage of loading condition, the soil will experience different behaviour (Ti *et al*., 2009). To solve this problem, use of Hardening Soil (HS) model in simulation and analysis comes into the application. HS model was framed based on the concept of plasticity theory and stress-dependent stiffness. The formulation and verification of the HS model were described in detail by Schanz *et al*. (1999).

This paper aims to show the simplified technique for surface settlement computation of tunnelling excavation based on the KVMRT project using the PLAXIS 2D software. This study will emphasize on the use of lining contraction and stress reduction method. This two-method used and back analysing of surface settlement due to tunnel excavation was done at the final stage of the study. The result of the two methods was compared and back analysing results verified with ground monitoring data to justify the method applied is valid. This study will benefit the underground excavation project in terms of understanding the effect of 2D modelling method and constitutive model for the prediction of twin tunnel induced surface settlement and its suitability to adopt for Finite Element analysis for better prediction of surface settlement in Kenny Hill Formation.

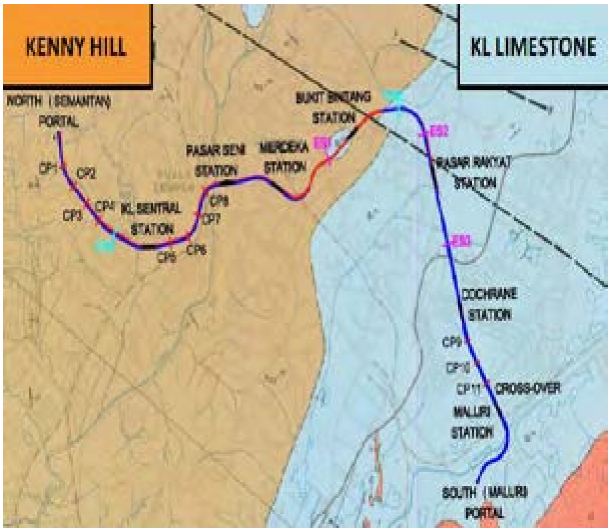

Figure 1: Two different geological formations along alignment of KVMRT Line One (Wallis & Kenyon, 2014).

STUDY AREA

Greater Kuala Lumpur or also known as Klang Valley is an urban area formed by Kuala Lumpur and its attached cities and towns with high rate of population. KVMRT is a transformation project of public transportation service in Kuala Lumpur which aims to upgrade the public transportation facilities. The twin tunnel alignment of KVMRT line, one which is named as the Sungai Buloh to Kajang (SBK Line) cut through two different geological formations specifically Kenny Hill Formation and Kuala Lumpur Limestone, as shown in Figure 1.

The geological and soil mechanical characterisation of Kenny Hill Formation and Kuala Lumpur Limestone are varied from one to another. As mention previously in this study, we only focus on the Kenny Hill Formation because the study of tunnel interaction in Kenny Hill Formation is still new. Kenny Hill Formation comprises of interbedded clastic sedimentary rocks such as siltstone, sandstone and shale.

The SBK line is about 51 km in length and consist of 31 stops which includes elevated and underground stations. About 9.5 km underground alignment with a tunnel diameter of 6.7 m of SBK line passes through the centre of Kuala Lumpur with a total of 7 stations, as shown in Figure 2.

METHODOLOGY

Basically, this study was divided into three major parts. The first part is subsurface characterization. Second is the empirical correlations of stiffness parameters and soil properties determination for the

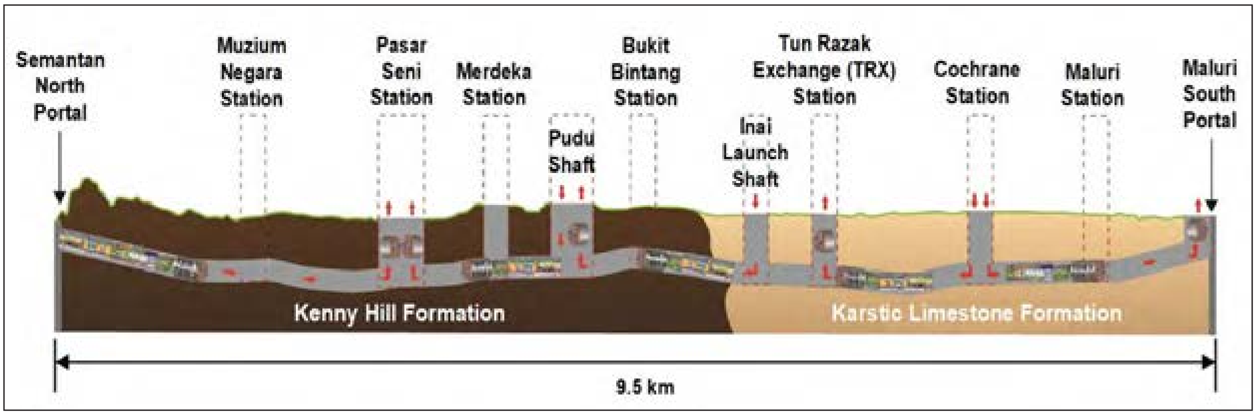

Figure 2: Scope of underground works (Wallis, 2015).

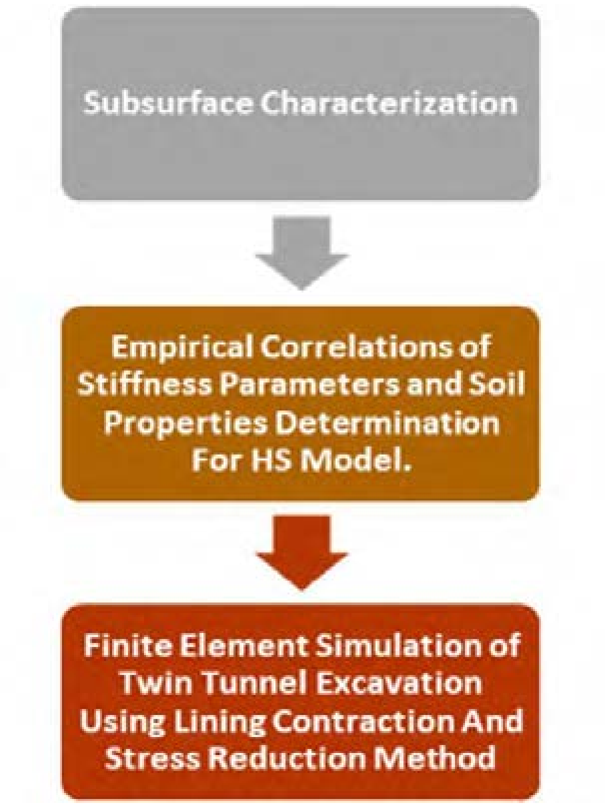

Figure 3: Methodology of study.

HS model. Lastly, the third part which is the Finite Element simulation of twin tunnel excavation using lining contraction and stress reduction method. Figure 3 shows the overall workflow of the study. Each part of the study is very important.

Subsurface characterization

All the information such as soil sampling data, in-situ testing data, bore log data and laboratory testing data are gathered to create subsurface modelling and characterization. The sum of bore log data is large for this project. The Standard Penetration Test (SPT-N) values and the soil lithology are studied in detail and categorized into few zones based on its subsurface information. This study only focusses on the one zone which contains a large percentage of fine-grained soil with a low percentage of coarse-grained and rock sample. With the help of RockWorks16 3D, the ground model is created using spatial interpolation method. Next, the tunnel filtered model is obtained from the 3D ground model. Information such as SPT-N value and soil type within the tunnel segment was obtained. Based on the output, two greenfield tunnel sections selected. The section also selected based on the availability of information such as existing monitoring data and soil test result. The selected chainage for this study is NB1590 and NB1960 as shown in Figure 4. Based on the soil profile, further analysis was done. The soil profile was simplified, so it can be easily inputted in the PLAXIS 2D software.

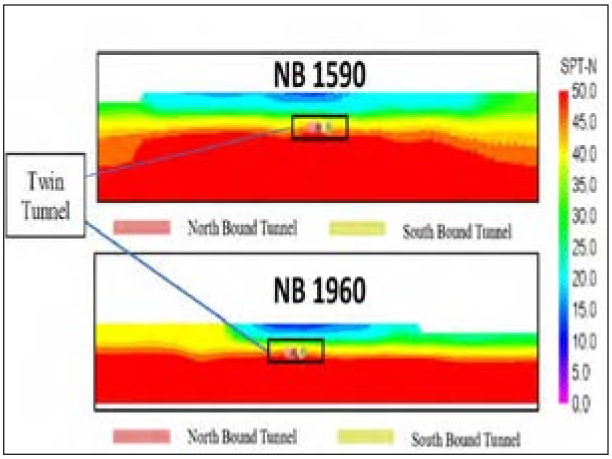

Figure 4: Cross section of selected tunnel.

Empirical correlations of stiffness parameters and soil parameters determination for HS model

The HS model involves more parameters compared to the Mohr-Coulomb Model. The three-main stiffness parameter that involves in the HS model is triaxial secant stiffness (E_{50}), oedometer stiffness (E_{oed}) and unloading-reloading stiffness (E_{ur}). For this study, the stiffness parameters for HS model in Kenny Hill Formation were determined based on the empirical correlation suggested by Law *et al*. (2014) and Tan *et al*. (2001). This correlation is based on SPT-N values, so the effective triaxial secant stiffness (E^{ref}_{50}) and effective oedometer stiffness (E^{ref}_{oed}) can be empirically correlated. Next, the effective unloading-reloading stiffness which is (E^{ref}_{ur}) is three times of the triaxial secant stiffness value. In the normal case, the effective oedometer stiffness (E^{ref}_{oed}) will be the same as effective triaxial secant stiffness (E^{ref}_{50}). The effective friction angle and cohesion which are the strength parameters were taken from triaxial test results. The empirical correlations were verified with numerical back analysis by using the two different sets of soil parameters that obtained from the empirical relationship. Table 1 shows the HS model parameters obtained from empirical correlation. Correlation based on 1.5 SPT-N as proposed by Law *et al*. (2014) was adopted for further analysis since it can agree well with the monitored settlement.

Finite element simulation of twin tunnel excavation using lining contraction and stress reduction method

Tunnel excavation method can be simulated in a two-dimensional plane. However, to convert the three-dimensional plane into a two-dimensional plane we need to consider certain aspects. We must assume the missing

Table 1: Soil parameters obtained from empirical correlation.

SPT-N	φ´	c´	γ_b	E^{ref}_{50}	E^{ref}_{oed}	E^{ref}_{ur}	v_{ur}	K_0^{NC}	p^{ref}	*m*
Correlation 1.5N (Law et al., 2014)										
5	31.75	8.75	18	7500	7500	22500	0.2	0.47	100	0.5
20	30.9167	4.83	18.5	30000	30000	90000	0.2	0.49	100	0.5
40	30.25	5	19	60000	60000	180000	0.2	0.50	100	0.5
50	29.8333	7.17	20	75000	75000	225000	0.2	0.50	100	0.5
Correlation 2.5N (Tan et al., 2001)										
5	31.75	8.75	18	12500	12500	37500	0.2	0.47	100	0.5
20	30.9167	4.83	18.5	50000	50000	150000	0.2	0.49	100	0.5
40	30.25	5	19	100000	100000	300000	0.2	0.50	100	0.5
50	29.8333	7.17	20	125000	125000	375000	0.2	0.50	100	0.5

dimension with other aspects. The lining contraction involves two phases. First is the deactivation of soil cluster in the tunnel. Then, the second phase is the step-wise application of tunnel contraction ratio. This method uses the contraction ratio to determine the best fit settlement curve with monitoring data. Next, the stress reduction method which uses an unloading factor (β) to consider the three-dimensional effect into the two-dimensional plane. For the stress reduction method includes three calculation phases. In the first phase, the initial support pressure (p_o) acts on the tunnel. This support pressure reduces to p_β, where p_β is the relationship of βp_o in the second calculation phase to help the surrounding soil to deform. The β value will be between 0 to 1. In the last phase, the soil cluster inside the tunnel is deactivated, the same time the tunnel lining is activated. For further details about lining contraction and stress reduction method can be referred to Likitlersuang *et al*. (2014). As mention, the procedure of lining contraction and stress reduction was done in the PLAXIS 2D software with the selected soil profile as shown in Figure 5.

Based on the soil profile and procedure both lining contraction and stress reduction method analyzed in PLAXIS 2D software to obtain a suitable range of contraction ratio and unloading factor for Kenny Hill Formation. The sequence of the simulation depends on the construction of twin tunnel. For this section, the North Bound (NB) excavated first and then only the South Bound (SB) continued for excavation. So, the simulation begins at NB and ends at the SB. Figure 6 shows an example of output from the lining contraction method for chainage NB 1590 in PLAXIS 2D software.

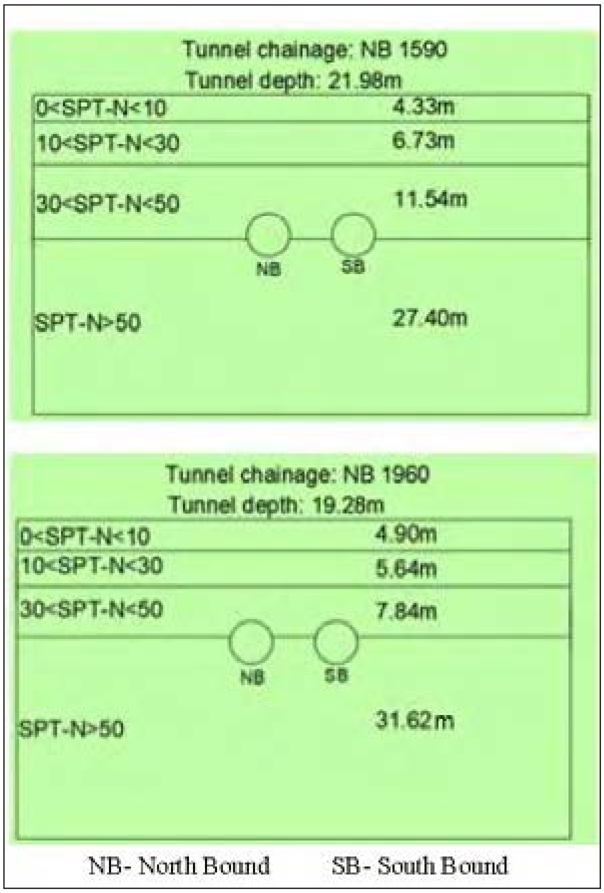

Figure 5: Soil profile of analysed sections.

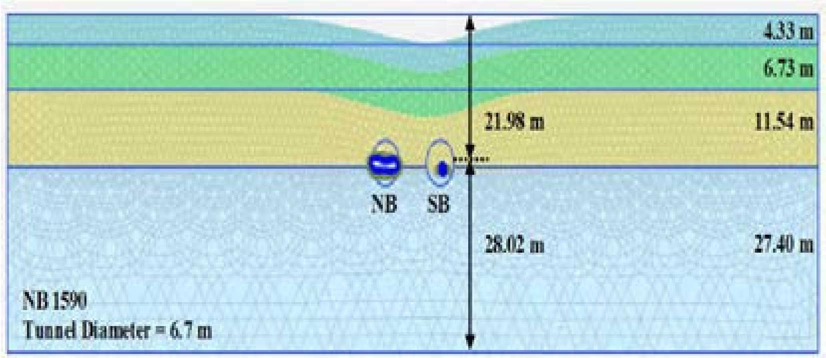

Figure 6: Finite Element Model (An example from NB 1590).

RESULTS AND DISCUSSION

The two sections of SBK Line were modelled using lining contraction and stress reduction method. The results of the simulation for the two sections are shown in Figures 7 and 8.

The simulated settlement curves for the two sections using both methods can fit back to the monitoring settlement with less difference and almost similar trend. Some of the monitoring settlement data of chainage NB 1590 was observed with a surface heave, this may be due to errors in the monitoring instrument. Table 2 summarized the maximum settlements from simulation and ground monitoring data. Table 3 shows the contraction ratio from lining contraction method and unloading factor from stress reduction method.

Stress reduction method fit back the curve better than lining contraction method. The difference of maximum settlement obtained from stress reduction to the monitoring data is less compare to the maximum settlement from lining contraction. From the contraction ratio results can say that higher the contraction ratio, higher the maximum settlement. For the stress reduction method higher the unloading factor, β the smaller the settlement. Can say that the relationship between contraction ratio and unloading factor is vice versa as shown in Figure 9. A good correlation was obtained between contraction ratio and unloading factor with R^2 of 0.9948.

CONCLUSION

This study emphasised the two-dimensional simulation of tunnel excavation. Lining contraction and stress reduction method was used to study the settlements. Two greenfield sections selected for the analysis. The contraction ratio of the two-section ranged from 0.25 to 0.50 and the unloading factor ranged from 0.30 to 0.68. The values are logical because it correlates well. This method can be used to solve tunnel problems especially ground settlements.

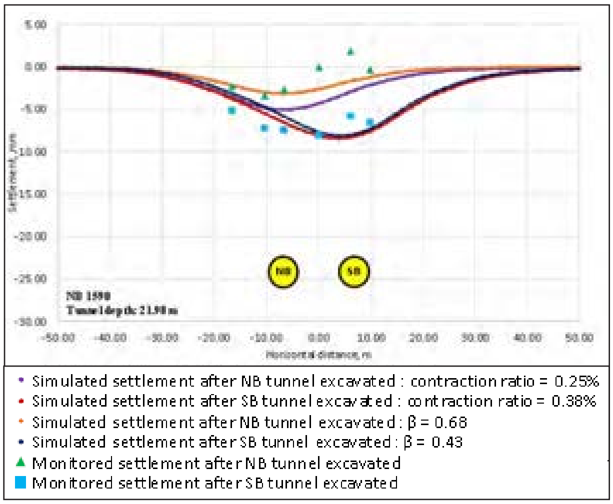

Figure 7: Results from the lining contraction and stress reduction method of chainage NB 1590.

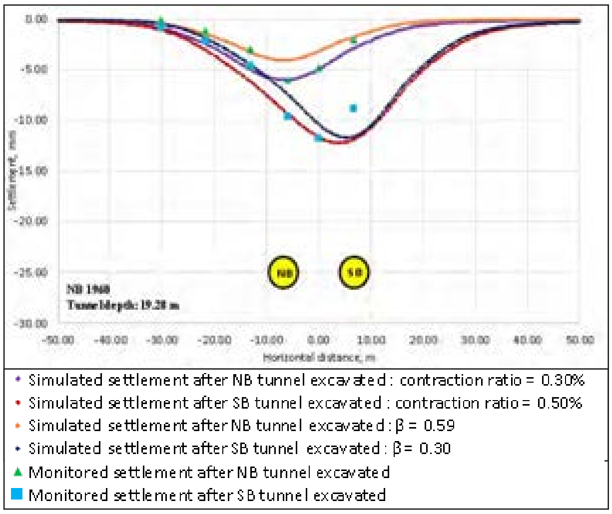

Figure 8: Results from the lining contraction and stress reduction method of chainage NB 1960.

Table 2: Maximum settlements from simulation and monitoring.

Tunnel Chainage	*Tunnel*	*Maximum settlement from lining contraction, mm*	*Maximum settlement from stress reduction, mm*	*Monitored maximum settlement, mm*
NB 1590	NB	5.042	3.21	2.63
	SB	8.445	8.16	8.13
NB 1960	NB	6.002	4.11	6.03
	SB	12.253	11.79	11.83

Table 3: Results of contraction ratio and unloading factor.

Tunnel Chainage	*Tunnel*	*Contraction ratio, %*	*Unloading Factor, β*
NB 1590	NB	0.25	0.68
	SB	0.38	0.43
NB 1960	NB	0.30	0.59
	SB	0.50	0.30

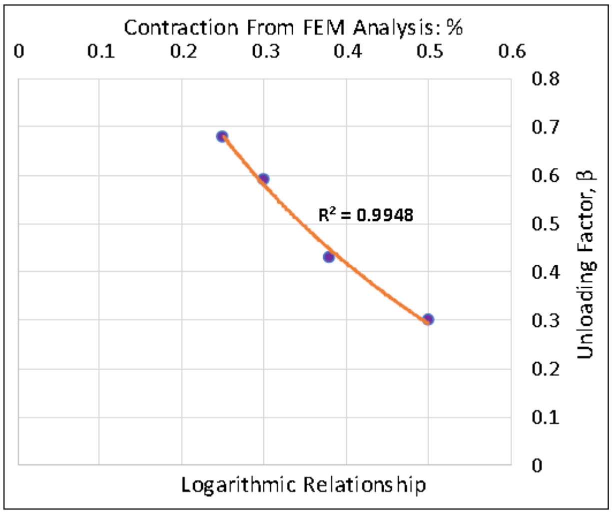

Figure 9: Relationships of contraction ratio and unloading factor.

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Slope stability assessment in opencast quarry – an UAV approach

Nur Emilia Qistina Mohd Anua, Hareyani Zabidi*, Aisyah Shahirah Juhari, Solihin Yaacob, Syaran Suri

Mineral Resources Engineering, School of Materials and Mineral Resources Engineering, Universiti Sains Malaysia, 14300 Nibong Tebal, Pulau Pinang, Malysia
* Corresponding author email: srhareyani.zabidi@usm.my

Abstract: Evaluation on the stability of rock slope is a prime, interesting and formidable aspect in environmental issues. The mechanics of instability depend commonly on nature, strength, and structures of the rock mass. In this research, the structure of rock mass was studied using a technological advanced tool, Unmanned Aerial Vehicle (UAV) to determine the stability of the selected quarry face. To achieve this, photogrammetric mapping and kinematic analysis were carried out consequently at Hume Cement Quarry in Gopeng. The results indicate that the quarry slope has ten (10) major discontinuity sets and there are two (2) possible modes of failure consist of wedge and toppling failure. The UAV approach in determining the stability of rock slope have a lot of advantages and the usage of UAV could be wider as it can be used in many sector.

Keywords: Discontinuities, UAV, photogrammetric mapping, quarry, Kinta Limestone formation

INTRODUCTION

The unfavourably oriented discontinuities with respect to the slope cutting orientation may results in instabilities or rock slope failure. The role of geology parameters on slope problems and assessment is variable, depends on the subsoil constituent and structures itself. Rock slope stability is a condition where slopes are stabilized against the possibility of instability for both cut and natural slope (Kamaruszaman & Jamaluddin, 2016).

The quarrying activities can cause various type of instabilities, especially when the development schemes do not depend on scientific process (Guadri *et al*., 2015; Hadji *et al*., 2016). In mining industries, main used methods to assess the slope stability of rock mass in open cast mines are rock mass classification system followed by kinematic analysis and limit equilibrium calculation. The methods are controlled by mechanical parameter, geological conditions, geometrical design, and discontinuities characteristics (Brady & Brown, 1993).

The purposes of this study are to determine the properties of major discontinuity set based on the 3D model from photogrammetric mapping and to assess the stability of the limestone quarry slope based on kinematic analysis.

GEOLOGICAL SETTING

Hume Cement Quarry is an open pit quarry located in Gopeng, Perak (Figure 1) that excavate limestone and process it into cement for multi-purpose. This limestone is part of Kinta Valley Formation or known as Kinta Limestone. Kinta Valley is characterized by remnant limestone hills sandwiched by the Triassic granitic batholiths (Cobbing *et al*., 1992) of the Kledang Range in the west and the Main Range in the east. There are three major facies in Kinta Valley; carbonate facies, argillaceous facies and arenaceous facies (Ingham & Bradford, 1960). The carbonate facies is known as Kinta Limestone Formation (Foo, 1983). The Kinta Limestone spanned from Silurian to Permian age and due to being exposed for a very long period of time, it is only visible as limestone hills or karst.

MATERIALS AND METHODS

For this study, a combination of two methods have been conducted to assess the slope stability of open pit quarry; the photogrammetric mapping and kinematic analysis. The first approach consist of data acquisition, along the selected rock section. The length of rock section investigated is about 55 m (Figure 2). The quarry face is almost vertical, with height of 15 m and was labelled as Window A. Data were collected by photogrammetry mapping using Unmanned

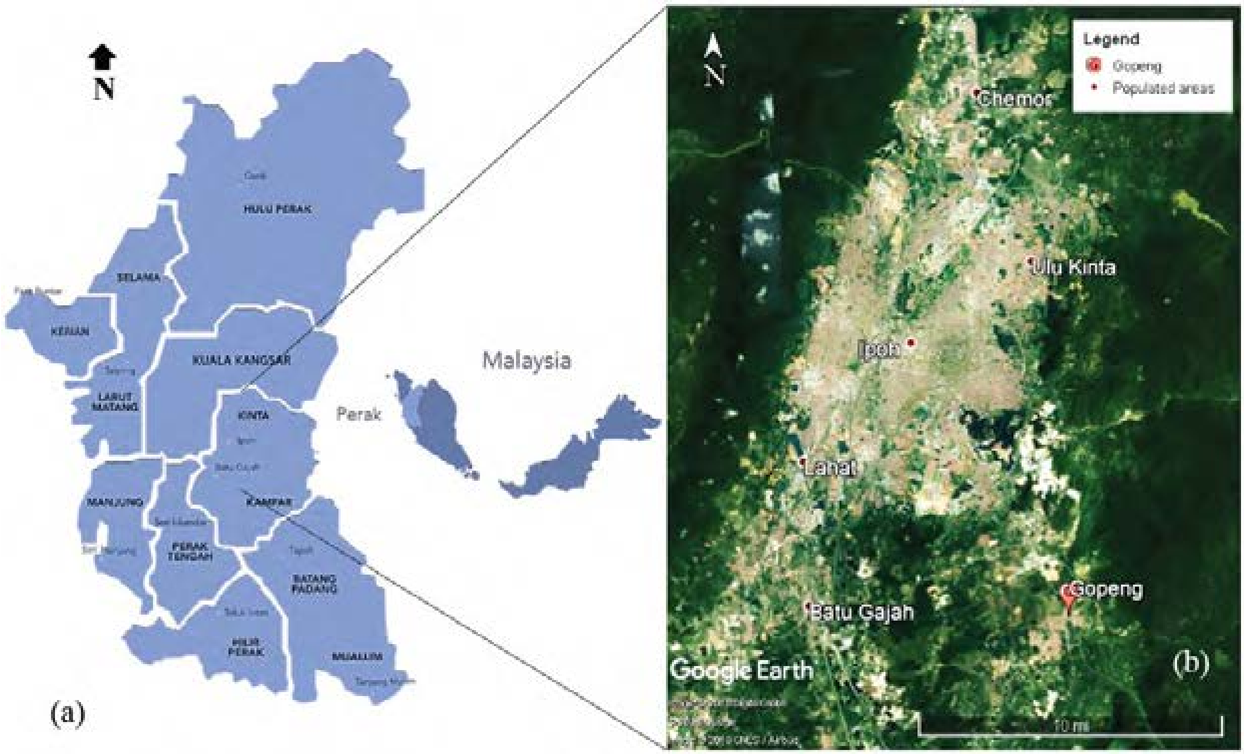

Figure 1: Maps of (a) distribution of Perak district; (b) location of Gopeng, Perak, Malaysia from Google Earth.

Figure 2: The quarry face of study area, Window A.

Aerial Vehicle (UAV) or drone. The gathered data were interpreted and analysed using software to obtain the 3D model and major joint set. The images taken at the site are first transferred to Agisoft Photoscan software to be modelled. The process in Agisoft Photoscan are using point cloud from the images taken. Discontinuity Set Extractor is used for kinematic analysis of discontinuities using stereographic projection method based on the information from the interpretation data of photogrammetric mapping. This analysis is applied to determine the stability of the rock section and possible mode of failures by using Dips 7.0.

RESULTS AND DISCUSSIONS

Drone mapping were done at Window A and 67 images were captured with different angles, so that the data collection are well presented. 3D model of Window A were constructed from all the images taken and are presented in Figure 3. From the 3D model, the discontinuities were analysed using Discontinuity Set Extractor (DSE) (Riquelme *et al.*, 2014) program. The program extracted the discontinuities from the model and present it in term of sets. Table 1 shows the properties of each discontinuity set that had been extracted from Window A. Stereographic projection of the discontinuity sets mentioned are plotted in Figure 4. From the table and figure below, J1 (237/34) shows the highest density and the most dominant orientation while J10 (321/65) has the lowest density of occurrence and the least dominant orientation for Window A. This results show similarities when compare with manual mapping, which have the most dominant orientation of 238/34 and so prove that the drone mapping is reliable to use. The collected discontinuity sets are projected in DSE program to discriminate each of the set and are presented in Figure 5.

The discontinuity sets obtained from photogrammetry mapping further used to study the kinematic properties of Window A. Results of kinematic analysis indicate that Window A have two potential mode of failures, which are wedge failure and toppling failure. Each discontinuity set is distinguished by different colour and symbol in the stereographic projection.

Wedge failure may occur at the quarry slope with 17.79% critical intersections. Details of the failure mode shown in Figure 6 where 8 out of 45 intersections detected.

There are 15.56% possibility of direct toppling to happen at Window A which include 7 out of 45 intersections. The details of the toppling failure is shown in Figure 7.

CONCLUSION

Ten (10) major discontinuity sets had been found at Window A with J1 has the highest density and J10 has the lowest density. From the 10 major sets, kinematic analysis shows that wedge failure had most possibility to be occurred while there are also possibility for toppling. As the assessment had been done, it is shows that the rock slope for Window A has high potential for instability to happen. By using UAV approach in determining the stability of a rock slope, a lot of advantages are gained from it. It saves a lot of time and helps to take reading at unreachable places.

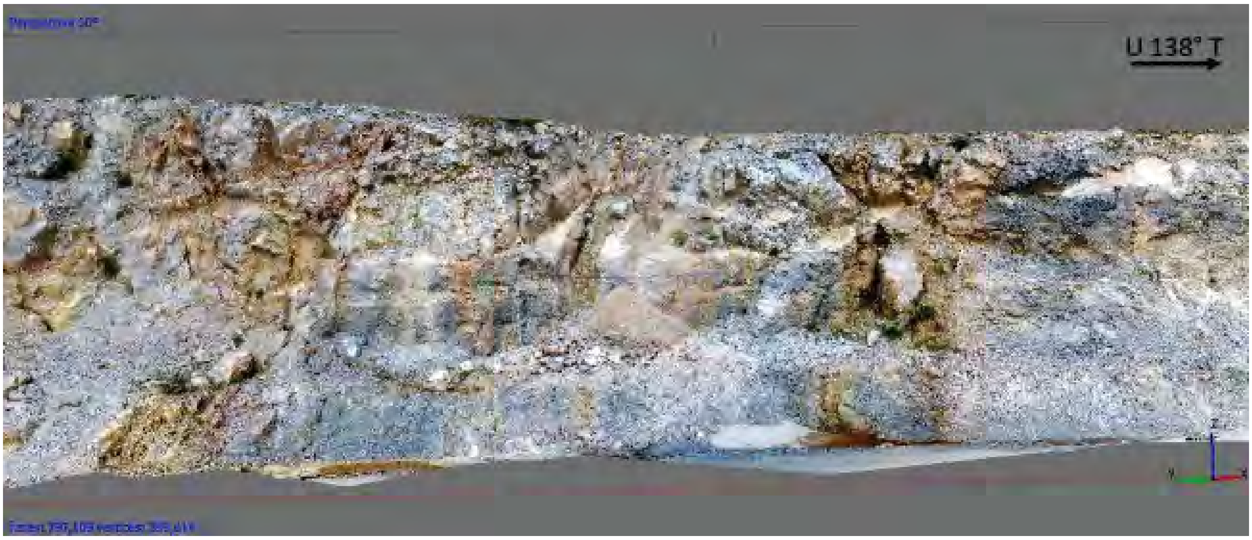

Figure 3: Model of Window A constructed from drone mapping.

Table 1: Properties of the 10 major discontinuity sets from DSE program.

Discontinuities joint set	Dip direction	Dip	Number of clusters	Number of points	Density
J1	237.52	34.49	495	430294	4.0755
J2	241.26	80.17	876	252696	0.9131
J3	65.32	88.21	597	175798	0.6382
J4	170.31	89.44	145	47771	0.4902
J5	195.75	87.94	707	41223	0.3743
J6	28.49	86.95	829	94509	0.3528
J7	185.19	76.54	583	80926	0.2802
J8	4.18	88.77	295	27113	0.2497
J9	33.11	66.35	442	42415	0.2432
J10	321.01	65.5	217	49348	0.1893

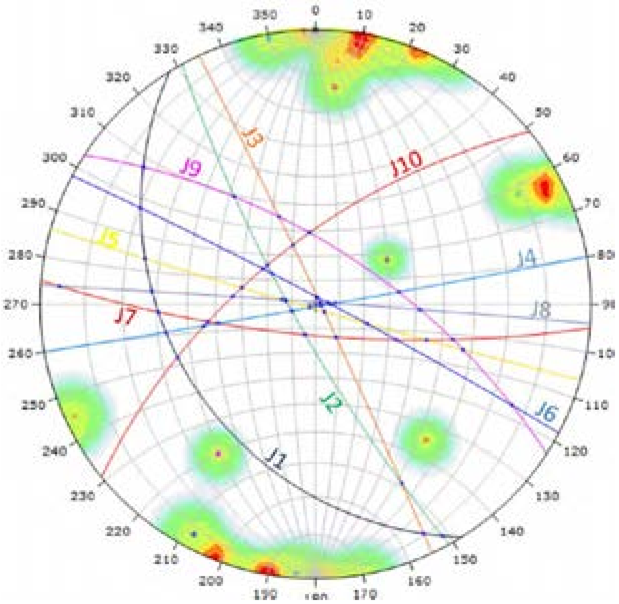

Figure 4: Stereographic plot of 10 major discontinuity sets found at Window A from the photogrammetric mapping.

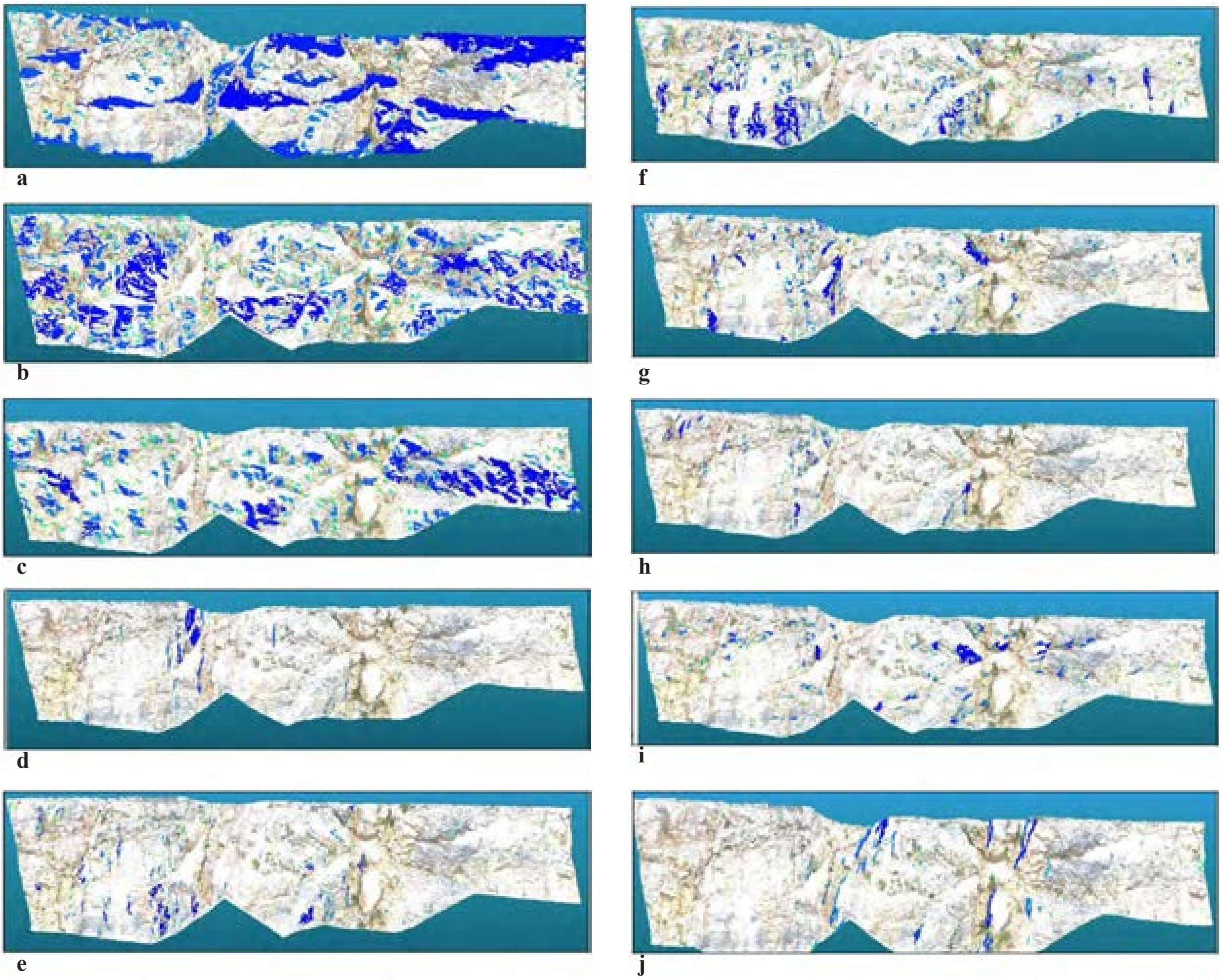

Figure 5: Each discontinuity sets interpreted by DSE program. The colors (blue and green) represent the discontinuity planes and difference of density for each set can be seen. (a) J1; (b) J2; (c) J3; (d) J4; (e) J5; (f) J6; (g) J7; (h) J8; (i) J9; (j) J10.

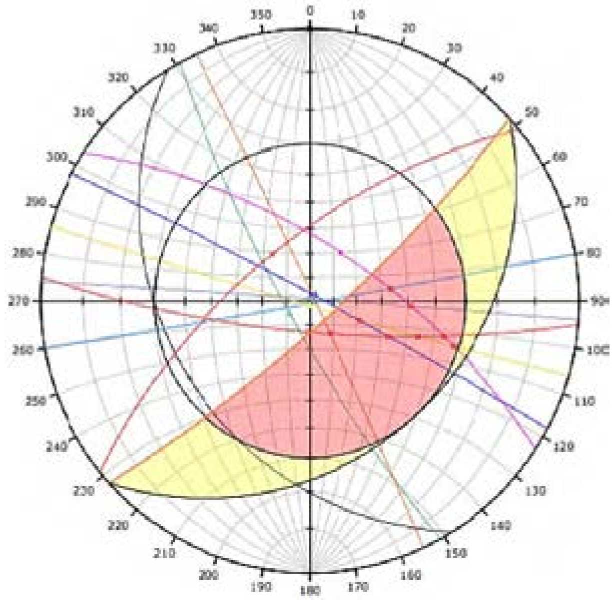

Figure 6: Kinematic analysis of wedge mode failure.

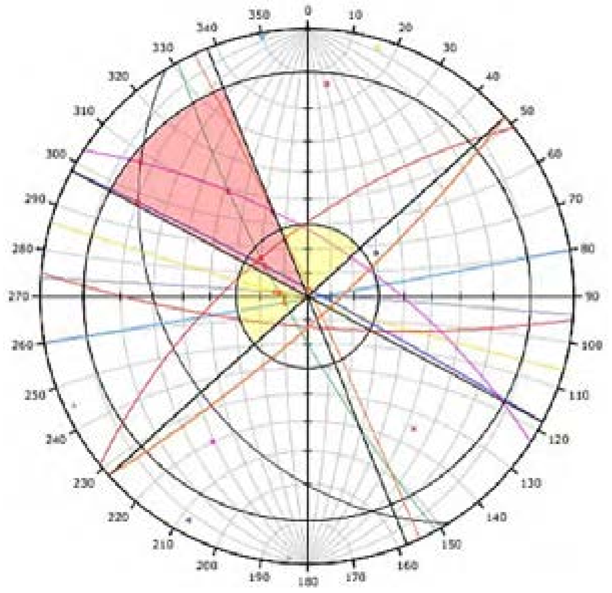

Figure 7: Kinematic analysis of toppling mode of failure.

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The contribution of technical ceramic to iron smelting production at Sungai Batu, Bujang Valley, Kedah

Naizatul Akma Mohd Mokhtar*, Mokhtar Saidin

Centre of Global Archaeological Research, Universiti Sains Malaysia, 11800 Pulau Pinang, Malaysia
* Corresponding author email address: naizatulm@gmail.com

Abstract: Iron smelting sites at Sungai Batu, Bujang Valley are dated from 788 - 537 BCE (Beta-516413) until 15th Century CE. The evidence of 17 sites found with the abundance of iron slags and other artefacts clearly show that a large scale of iron-smelting industry existed in Bujang Valley. The term 'technical ceramics' refers generally to any ceramics used in metallurgical or other high-temperature operations. The technical ceramic found in archaeological sites can be classified as furnace, tuyere and brick. They were made from clay and play different roles for iron smelting process. This article will discuss the significant of technical ceramic regarding the impact of iron production. The methods consist of collecting sample from archaeological site, augering sample and scientific analysis such as X-ray fluorescence (XRF), X-ray diffraction (XRD) and scanning electron microscopes-energy dispersive X-ray (SEM-EDX) analysis. The following discussion will further explain the selection of material and particular shapes in enhancing the iron smelting process at Sungai Batu. The result demonstrate that the technical ceramics were made from the locally available with some sand as temper.

Abstrak: Tapak peleburan besi di Sungai Batu, Lembah Bujang berusia dari 535 Sebelum Masihi hingga kurun ke-15 Masihi. Bukti 17 tapak yang dijumpai dengan sisa besi dan artifak lain jelas menunjukkan bahawa industri besi berskala besar wujud di Lembah Bujang, Istilah 'seramik teknikal' secara umum merujuk kepada seramik yang digunakan dalam operasi mertalugi atau operasi lain yang menggunakan suhu tinggi. Seramik teknikal yang terdapat di tapak arkeologi dapat diklasifikasikan sebagai relau, tuyere dan bata. Artifak ini diperbuat daripada tanah liat dan mempunyai fungsi yang berbeza dalam proses peleburan besi. Artikel ini akan membincangkan kepentingan seramik teknikal terhadap penghasilan besi. Kaedah analisis melibatkan pengumpulan sampel dari lapangan, penggerudian cetek dan analisis saintifik secara pendarfluor sinar-X (XRF), pembelauan sinar-X (XRD) dan mikroskop electron-sinar X penyebaran tenaga (SEM-EDX). Perbincangan juga akan menjelaskan lebih lanjut pemilihan bahan dan bentuk tertentu dalam meningkatkan proses peleburan besi di Sungai Batu. Hasil kajian menunjukkan bahawa seramik teknikal diperbuat dari kawasan tempatan dengan sedikit pasir sebagai bajaan.

Keywords: Technical ceramics, iron smelting, Bujang Valley, tuyere, furnace

INTRODUCTION

Sungai Batu site was first discovered during a survey in 2007 (Mokhtar *et al.,* 2011). A survey of Sungai Batu estates, an area of four-square km, revealed a total of ninety-seven mounds, potential protohistoric sites of the Bujang Valley. Excavations from 2009 until recent have uncovered monument site function as a ritual site, 11 structures of jetty, 16 administrations building and 17 iron smelting sites.

Iron smelting sites at Sungai Batu, Bujang Valley are dated from 788 - 537 BCE (Beta-516413) until 15th Century CE (Naizatul & Mokhtar, 2018 & 2019). The iron smelting site reveals iron slag, iron ore, technical ceramics and deposits remains such as ash and charcoal. Iron are produced using direct method which is also refered as bloomery process. In simplified terms, this involved reducing part of the iron oxides of the charge to metal particles that coalesced to form a bloom, consisting of iron uniformly mixed with slag that required hammering to be wrought iron (Rostoker & Bronson, 1990).

The technical ceramics are one of the dominant discarded material in smelting process besides iron slag. The term 'technical ceramics' refers generally to any ceramics used in metallurgical or other high-temperature operations (Martinón-Torres & Rehren, 2014). Technical ceramics are essential tools for almost all metallurgical processes and were routinely exposed to a variety of conditions that they had to cope with (Martinón-Torres & Rehren, 2014). The technical ceramic found in archaeological sites can be classified as furnace, tuyere and brick. They were made from clay and have a different role to iron smelting process.

This paper explores the role technical ceramics play in various aspects of the Sungai Batu iron smelting site and the selection of the best material for technical ceramic. The main focus will be with the furnace and tuyères and the source of the raw material.

METHODOLOGY

The method consists of collecting sample from archaeological site and augering sample for scientific analysis such as X-ray fluorescence (XRF), X-ray diffraction (XRD) and scanning electron microscopes-energy dispersive X-ray (SEM-EDX) analysis. The sampling process involved tuyere and furnace pieces from SB2A, SB2C, SB2F, SB2H, SB1G and SB1ZY site (Table 1).

The augering sampling using AMS basic soil auger kit covered the area near the ancient river of Sungai Batu. The location of the drilling was randomly selected in the area near the ancient river by referring to the result done in 2009 (Nor Khairunnisa, 2009). A total of six clay samples were collected from three different localities (Log 1, Log 2, Log 3) (Figure 1).

CLAY SOURCE

Sungai Batu Complex area was situated between Gunung Jerai (north) and Sungai Muda (south) within

Table 1: Sample type and location.

Type	Sample No.	Location	Sample No.	Location
Clay	C1	Log 1, AD:105cm	C4	Log 2, AD:150cm
	C2	Log 1, AD:130cm	C5	Log 3, AD:120cm
	C3	Log 2, AD:100cm	C6	Log 3, AD:158cm
Furnace	D1	SB2A (Q10)	D6	SB2F (J9)
	D2	SB2A (O10)	D7	SB2F (K9)
	D3	SB2C (K16)	D8	SB1ZY (H5)
	D4	SB1G (J11)	D9	SB1ZY (J6)
	D5	SB1G (J12)	D10	SB2H (N1)
Tuyere	T1	SB2A (P15)	T7	SB2F (T4)
	T2	SB2A (R8)	T8	SB2F (G8)
	T3	SB2C (M25)	T9	SB1ZY (G8)
	T4	SB2C (L28)	T10	SB1ZY (J12)
	T5	SB1G (F14)	T11	SB2H (J12)
	T6	SB1G (T10)	T12	SB2H (S5)

*AD: Actual Depth; ( ): trench

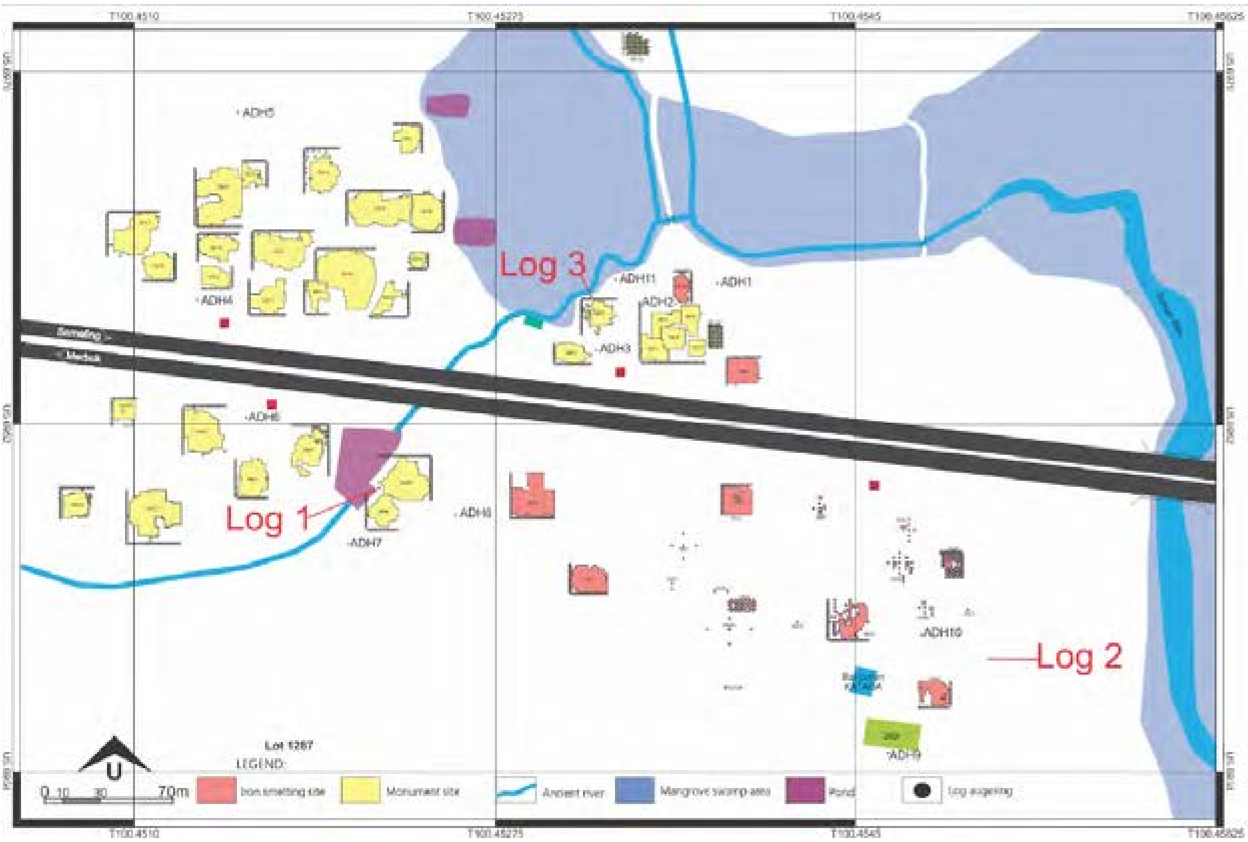

Figure 1: The location of iron smelting site and augering samples.

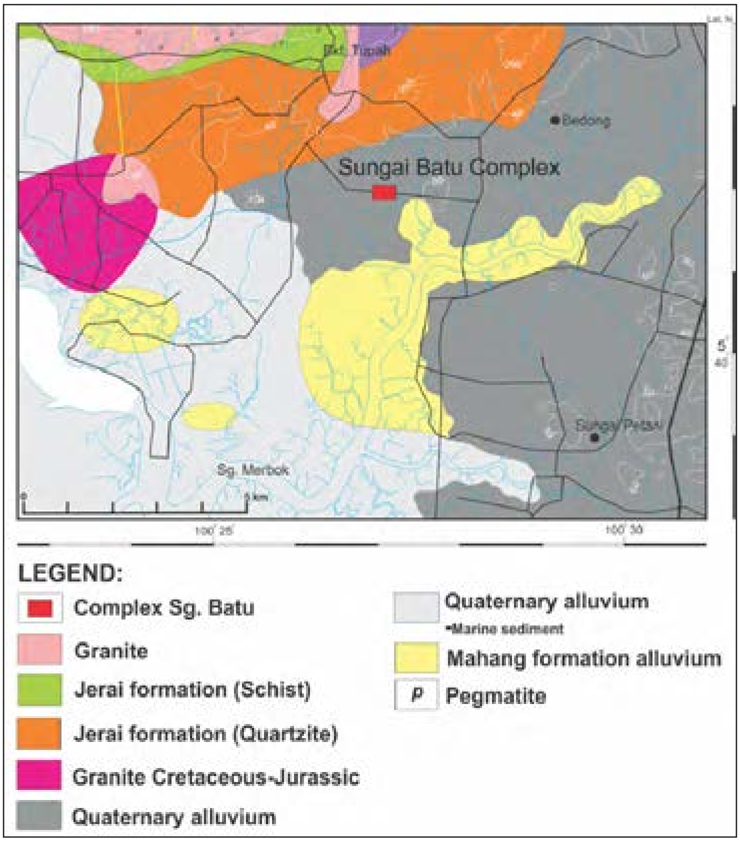

Figure 2: Geological map of the study area.

Kuala Muda, Kedah. The study area is an alluvial land with abundant iron ore distribution in the southern part of Kampung Merbok (Bean, 1969; Bradford, 1972) (Figure 2). The soil types of the area are sandy clay covered with fine sand. There are few small rivers and swamp area at the eastern part of the area.

FURNACE

Furnaces are typically immobile structures that contain the charge, such as charcoal and minerals, and are used for the smelting of ore to metal iron (Martinón-Torres & Rehren, 2014). Furnace found at iron smelting site are in fragmented pieces and the remains of the furnace can be seen at the base (Figure 3). They are in small pieces, irregular shapes and were made from clay. The width of the furnace remains are estimated around 100 cm and there were two to three furnace remains found in each site.

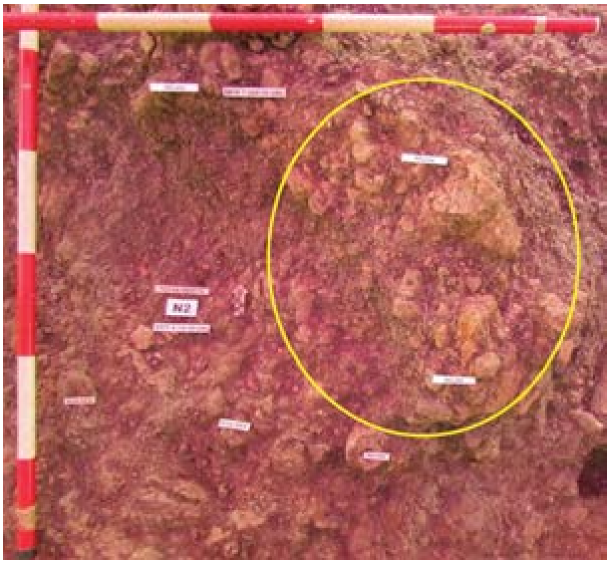

Figure 3: Remaining furnace.

TUYERE

Tuyere is one of the important tools in ancient iron smelting. Its main function is to control and balance the combustion temperature during the smelting activity. The hole in the center of the tuyere allows the air supply and oxygen that are needed to increase the temperature in the furnace (Figures 4 & 5). Most of the tuyeres found at the iron smelting site are in broken shapes. They are classified as a waste product and more than hundred thousand fragmented pieces have been excavated so far. The recorded number of tuyere represent only artefacts that have been excavated, yet there are more still uncounted which are buried in the mound.

Figure 4: Tuyere.

Figure 5: Tuyere from the sideview.

A 'complete' tuyere means that it ranges from a rear end where the bellow was inserted, to a vitrified nozzle (inside the furnace) (Veldhuijzen, 2005). A total of 101 complete tuyeres have been taken out from the field. No definite conclusions can be drawn about the original full length of the tuyères but the longest tuyere found measured about 27.1 cm (length) and 11.2 cm (width). The inner diameter of the tuyere (inner hole) is approximately 2.1 cm to 3.6 cm (Figure 6).

This analysis of complete tuyeres show that they were made with standardization in shape and size. The standardization of tuyere production helps to increase maximum efficiency for the smelting operations. The air blown in from the tuyeres does affect the reduction process in the furnace (Friede *et al.*, 1984). The features of tuyeres also suggested that a hand technique was used to form the objects and have been molded around a stick to make the hole (Venunan, 2011).

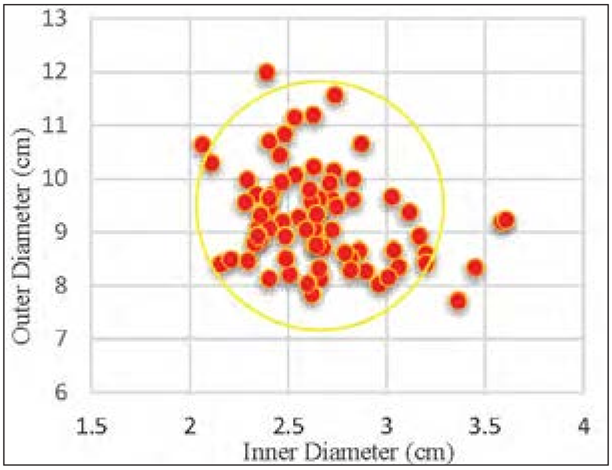

Figure 6: Diagram of diameter samples of tuyere for inner and outer diameter.

RESULT

The XRD results show that the minerals found in the furnace and tuyeres are quartz, dickite, rutile, mullite, cristobalite, tridymite, montmorillonite, diaspore, muscovite, microcline, fayalite, anorthite, hematite, dolomite and magnemite (Table 2). There are many high temperature phase minerals (e.g., mullite, cristobalite and tridymite) which transformed from kaolinite and quartz, found in the furnace and tuyere samples. Quartz, dickite, rutile, diaspore and muscovite can be found in the clay samples. Kaolinite and quartz undergo some significant changes in its structure when heated to higher temperatures. Mineral transformation series was made over the range: kaolinite-mullite 950-1500°C, quartz-tridymite 866.85-1469.85°C and cristobalite 1469.85-1679.85°C. The quartz was added as a temper, which would have improved the toughness and thermal shock resistance of these technical ceramics (Venunan, 2011).

The XRF analyses present a ceramic matrix with approximately 65-75 wt% SiO_2 and roughly 10-17 wt% Al_2O_3 (Table 3). The higher SiO_2 and Al_2O_3 content in technical ceramics can be explained by the nature of technical ceramics which need to be more refractory, and silica in this case influenced the level of technical ceramics to be tolerant enough to survive the operation (Venunan, 2011). The percentage ratio of alumina to silica for 10 furnace samples is between 1: 4.1 to 1: 7.5 (Table 3). On the other hand, the percentage ratio of alumina to silica in the manufacture of tuyere is between 1: 3.9 to 1: 4.6. Comparison of alumina ratio to silica between furnace and tuyere shows that the use of silica (sand) in the furnace manufacturing was more than in the tuyere production. This is due to the need for the furnace structure to last longer and the presence of quartz as a temper can increase the resistance to high temperatures (Venunan, 2011). The temperature at the bottom of the furnace is higher compared to at the other parts of the furnace, where the temperature is about 1200°C (Thiele, 2010).

Observation under the optical microscope show that quartz grains are predominant in the fabric of technical

Table 2: XRD results.

Sample no.	Mineral																
	Q	Kao	Dic	Rut	Kris	Mul	Tri	Mont	Dia	Mus	Illite	Micro	Fay	Anor	He	Do	Magn	Mag
C1	•	•	-	-	-	-	-	-	-	•	-	-	-	-	-	-	-	-
C2	•	•	•	•	-	-	-	-	-	•	-	-	-	-	-	-	-	-
C3	•	•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C4	•	•	-	-	-	-	-	-	•	-	-	-	-	-	-	-	•	-
C5	•	•	-	-	-	-	-	-	•	-	-	-	-	-	-	-	-	-
C6	•	•	-	-	-	-	-	-	•	•	-	-	-	•	-	-	-	-
D1	•	-	-	-	-	-	-	•	•	-	-	-	-	-	-	-	-	-
D2	•	-	-	-	-	-	-	•	-	-	-	-	-	-	-	-	-	-
D3	•	-	-	-	-	-	-	-	-	•	-	-	•	-	-	-	-	-
D4	•	-	-	-	-	-	-	•	-	-	-	-	-	-	•	-	-	-
D5	•	-	-	-	-	-	-	•	-	-	-	-	-	-	•	-	-	-
D6	•	-	-	-	-	-	-	•	-	-	-	-	-	•	-	-	-	-
D7	•	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	-	-
D8	•	-	-	-	-	-	-	•	-	-	-	-	-	-	-	-	-	-
D9	•	-	-	-	-	-	-	•	-	-	-	-	-	-	-	-	-	-
D10	•	-	-	-	-	-	-	•	-	•	-	-	-	-	-	-	-	-
T1	•	-	-	-	•	•	-	-	-	-	-	-	-	-	-	-	-	-
T2	•	-	-	-	-	-	-	-	-	•	-	-	-	-	-	-	-	•
T3	•	-	-	-	-	•	-	-	-	-	-	-	-	-	-	•	-	-
T4	•	-	-	-	•	•	-	-	-	-	-	-	-	-	-	-	-	-
T5	•	-	-	-	-	-	-	•	-	-	•	-	-	-	-	-	-	-
T6	•	-	-	-	•	•	-	-	-	-	•	-	-	-	-	-	-	-
T7	•	-	-	-	•	•	-	-	-	-	-	-	-	-	-	-	-	-
T8	•	-	-	-	-	-	-	•	-	•	-	-	-	-	-	-	-	-
T9	•	-	-	-	•	•	-	-	-	-	-	-	-	-	-	-	-	-
T10	•	-	-	-	-	-	-	•	-	-	-	•	-	-	•	-	-	-
T11	•	-	-	-	•	•	•	-	-	-	-	-	-	-	-	-	-	-
T12	•	-	-	-	-	-	-	•	•	-	-	-	-	-	-	-	-	-

Notes: Q: quartz, Kao: kaolinite; Dic: dickite; Rut: rutile; Mul: mullite; Cris: cristobalite; Tri: tridymite, Mont: montmorillonite; Dia: diaspore; Mus: muscovite; Micro: microcline; Fay: fayalite; Anor: anorthite; He: hematite; Do: dolomite; Magn: magnetite; Mag: magnemite

ceramics. The SEM analysis revealed that all technical ceramic samples are exposed to high temperature, as shown by the presence of cracked quartz and dissolved clay matrix (Figures 7 and 8). The cracked and dissolved quartz indicate that a fluxing agent for lowering the temperature to dissolve quartz were added in the smelting operation. The molten technical ceramic contributes actively to the formation of the slag (Veldhuijzen, 2005). Therefore, this will facilitate the production of the metal.

In order to assess the clays that was used to produce the technical ceramics, the chemical composition of clay samples was compared with the technical ceramics (Figure 9). The comparison of bulk compositions also demonstrates the similarity between the technical ceramic and the clay samples from three localities above 100 cm to 130 cm. The results clearly show that the raw materials were collected near the ancient river of Sungai Batu, with the estimated depth 100 cm to 130 cm.

CONCLUSION

The technical ceramics found at Sungai Batu iron smelting site play a large and crucial role in the iron

Table 3: XRF result.

Sample no.	Chemical composition (% Weight)										
	SiO_2	TiO_2	Al_2O_3	Fe_2O_3(t)	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Cl	SO_3
C1	69.72	0.94	16.09	1.04	0.01	0.20	0.06	0.10	0.48	0.08	-	-
C2	59.67	0.91	24.30	1.29	0.01	0.17	0.05	0.10	0.43	0.03	-	-
C3	72.28	0.74	14.70	1.54	0.01	0.24	0.06	0.09	0.51	0.03	-	-
C4	64.67	0.83	20.87	1.22	0.02	0.26	0.06	0.13	0.73	0.03	-	-
C5	65.53	0.66	15.32	2.07	0.01	0.31	0.12	0.39	0.73	0.04	-	3.31
C6	53.02	1.04	29.00	1.38	0.02	0.28	0.06	0.27	1.43	0.05	-	-
D1	75.74	0.54	11.91	2.74	0.17	0.33	0.46	0.15	0.51	0.04	-	-
D2	68.26	0.69	15.12	3.04	0.03	0.31	0.45	0.35	0.41	0.06	-	-
D3	63.66	0.62	15.54	2.57	0.05	1.06	0.96	1.27	0.44	0.10	3.74	-
D4	65.20	0.60	10.97	12.7	0.16	0.27	0.38	0.39	0.36	0.13	-	-
D5	62.94	0.64	11.71	13.86	0.13	0.18	0.21	0.06	0.38	0.12	-	-
D6	77.16	0.52	10.33	2.97	0.03	0.17	0.11	0.11	0.32	0.05	-	-
D7	71.97	0.92	15.40	4.19	0.02	0.32	0.06	0.03	0.25	0.05	-	-
D8	74.90	0.70	10.61	3.09	0.01	0.27	0.05	0.04	0.52	0.04	-	-
D9	69.11	0.77	12.38	6.49	0.01	0.24	0.05	0.04	0.66	0.09	-	-
D10	65.92	0.74	13.78	4.80	0.12	0.50	2.14	0.08	0.36	0.12	-	-
T1	74.03	0.62	17.03	1.92	0.02	0.24	0.07	0.18	0.70	0.04	-	-
T2	72.86	0.57	12.64	2.15	0.07	0.18	0.24	0.12	0.32	0.07	-	-
T3	70.52	0.83	17.16	5.21	0.01	0.33	0.04	0.13	0.34	0.06	-	-
T4	72.16	0.75	14.66	4.98	0.02	0.55	0.64	0.05	0.86	0.07	-	-
T5	72.16	0.74	13.64	3.07	0.01	0.11	0.08	0.05	0.50	0.07	-	-
T6	71.94	0.77	16.56	3.93	0.02	0.30	0.04	0.05	0.35	0.09	-	-
T7	73.28	0.77	16.42	2.98	0.02	0.23	0.05	0.09	0.24	0.08	-	-
T8	67.70	0.85	19.23	2.17	0.01	0.17	0.04	0.12	0.33	0.07	-	-
T9	72.34	0.84	18.35	3.41	0.01	0.28	0.04	0.06	0.25	0.04	-	-
T10	68.47	0.78	15.27	4.39	0.01	0.26	0.04	0.11	0.73	0.04	-	-
T11	68.80	0.97	21.36	2.43	0.01	0.35	0.05	0.24	0.51	0.07	-	-
T12	72.69	0.66	13.96	2.11	0.01	0.15	0.04	0.11	0.36	0.07	-	-

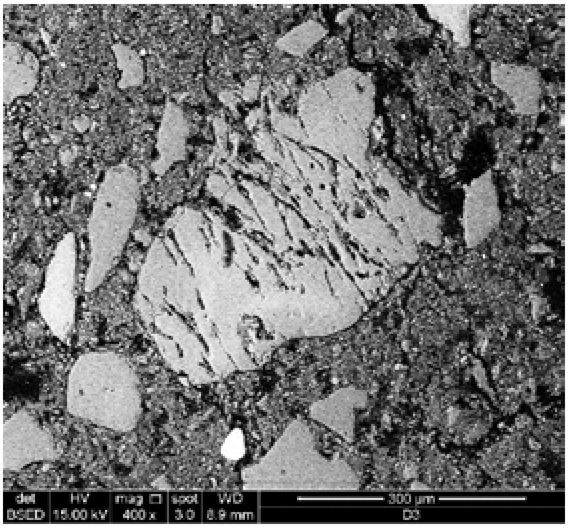

Figure 7: The quartz grains in furnace sample show cracks caused by the heat.

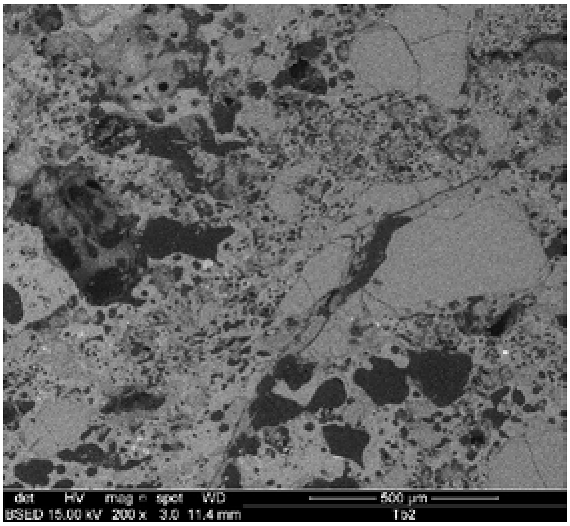

Figure 8: The vitrified region of tuyere show cracked quartz grains and dissolved clay matrix.

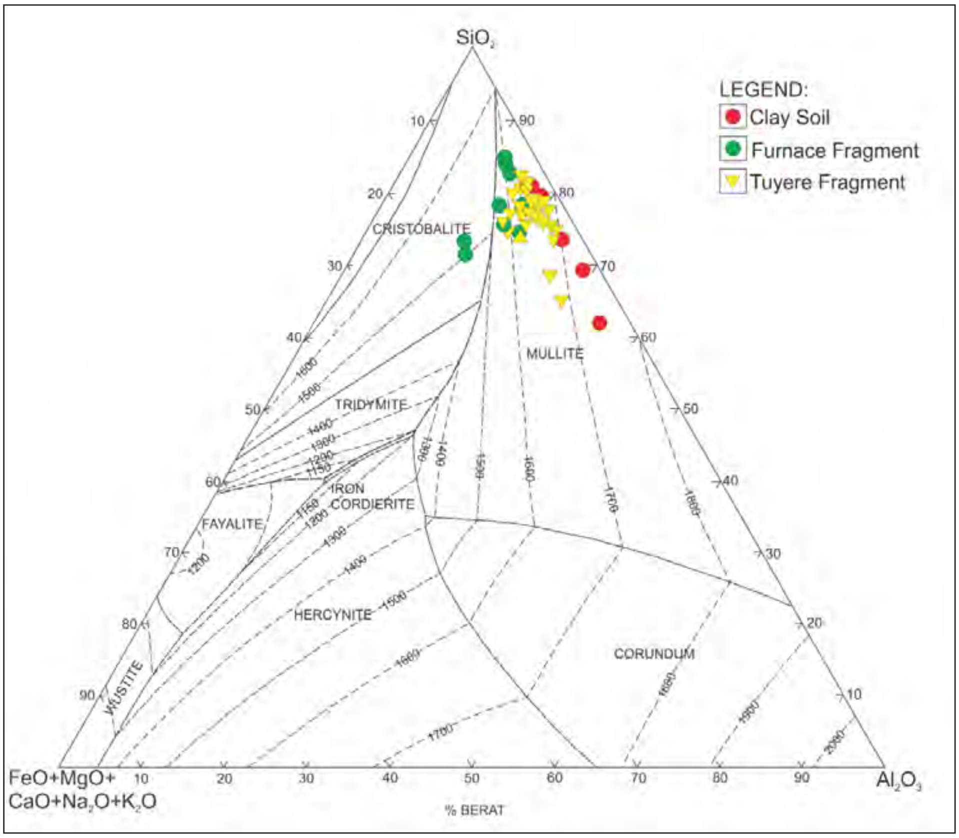

Figure 9: Ternary diagram showing bulk compositions of two technical ceramics compared with clay sample.

smelting operations. From the physical appearance of the tuyeres alone, it can be concluded that a shaft furnace as well as bellows were used. The high number and standardized size and shape of the tuyeres found at Sungai Batu shows that the industry was operating a big scale production. The typical cylinder shape of the tuyeres may tie in with local or regional metallurgical traditions or technological choice. From the combination of these physical and chemical data, it can be concluded that the Sungai Batu smelters purposefully applied tuyeres to facilitate the production of iron. The functions of furnace were not only focused on the temperature they could be sustained but also the selection of best raw material for increasing the production of iron. The site which is located in the direct vicinity of natural resources required in iron production such as water, ore and clay made the Sungai Batu Complex as a strategic location for iron industry.

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Rock slope discontinuity extraction from 3D point clouds: Application to an open pit limestone quarry

Syaran Suri*, Aisyah Shahirah Juhari, Solihin Yaacob, Nur Emilia Qistina Anua, Hareyani Zabidi

Mineral Resources Engineering, School of Materials and Mineral Resources Engineering,
Universiti Sains Malaysia, 14300 Nibong Tebal, Pulau Pinang, Malaysia
* Corresponding author email address: syaransuri@gmail.com

Abstract: Discontinuities dominantly play a key role in the mechanical, hydraulic, and deformational behaviors of rock masses, frequently impose significant influence on the stability of rock slopes. Thus, it is important to have a profound knowledge on the discontinuity network in rock engineering. This paper focuses on the identification of plane within 3D point clouds using the Discontinuity Set Extractor (DSE) program in MATLAB® (The Mathworks Inc.). The 3D point clouds were generated using the Agisoft PhotoScan Professional digital photogrammetry software (version 1.1.6) from photos captured via UAV method. To verify the plane identification, the photogrammetric results were compared with the manual mapping generated using the scanline method. Rosette plot for both methods revealed discontinuities set of similar direction but different in quantity. The most dominant discontinuities orientation was in the NNW-SSE direction at N330° - N340°, while the least dominant orientation took place in the E-W direction at N080° - N090°. The reliability of the discontinuity models was enhanced using the Structure from Motion (SfM) technique.

Keywords: Open pit quarry, discontinuity, Point clouds, UAV

INTRODUCTION

Open pit mining is a commonly implemented mining method in quarrying industry. The advantages of this method are larger minerals and ore yield, flexible planning along with pit progress, greater tonnage for each blast, and most importantly, creates less pollution compared to other typical mining methods. However currently in Malaysia, only a few open pit quarries are still in operation. Having said that, the open pit mining method also demonstrates certain limitations. These include excessive overburden removal, backfilling, and dumping in excavation areas. Thus, the design of benching system is crucial for this particular type of mining method. Moreover, frequent activities of blasting and excavation at slope surfaces will introduce problems in slope stability due to discontinuities . In comparison, the instability of open pit slope is different than the implications from civil works, where the excavation of an open pit is more extensive and prone to rock falls. Generally, the slope for an open pit mine is designed and constructed as steep as possible to avoid the uneconomical excavation of waste rock.

On the other spectrum, natural factors such as variation in rock mass conditions, rock slope material characterization, face angle, and also discontinuity orientation impose significant effects on the stability of rock slope. Discontinuity refers to most types of joints, weakness zone, bedding planes, fault, and schistocity planes of a rock mass with low or zero tensile strength (ISRM, 1978). Such that, fractures and discontinuities in rock masses are the most significant hydrogeological features that allow the storage and movement of fluid through them. In rock mechanics and mining, specifically, discontinuity itself affects the rock mass properties, therefore, it is important to comprehensively understand discontinuities in details.

Slope stability problems due to all the above mentioned factors have attracted major concerns from researchers and practitioners, and consequently, several techniques and methods for slope stability evaluation have been proposed. Some of these methods are kinematic analysis, limit equilibrium, numerical modeling, and empirical methods (Basahel & Mitri, 2017).

The characterization of rock masses requires the acquisition of information, which was traditionally collected by means of fieldwork, using a compass and a tape. Traditional methods for acquiring discontinuity data in field include the scanline survey and cell mapping (Priest, 1993; Nicholas & Sims, 2001). The sampling process involves a manual survey performed by an operator directly on the rock mass (ISRM, 1978). In a scanline survey, fracture data is garnered along a line on a rockface. For cell mapping, the dominant structures (joint sets, faults, etc.) on a rockface are first identified and the average information (orientation, spacing, length, etc.) is then measured for each geological structure. Scanline surveys provide thorough information on individual fractures in each set that can be used in probabilistic design, whereas cell mapping only gives average information about each joint set. Nevertheless, the collection of fieldwork data is time-consuming, and the data quality may be affected by the user's experience (Slob *et al*., 2010). The results are often subjective rather than objective and therefore are not reproducible (Gaich *et al*., 2006, Kemeny & Post 2003). In addition, rockfaces are often unsafe due to loose rock structure at the base of slopes, leading to potential rockfall of blocks. Getting an access to rockfaces is often difficult or impossible. Considering the operators' safety during a slope stability survey and the problems related to direct access to slopes, many researchers have proposed non-contact methods, namely, procedures which allow one to perform a trace survey on a representative rock mass via image scanning or a digital model.

The acquisition of 3D information through photogrammetric techniques has long been applied by geoscientists; most notably owing to their capability to visualize the Earth's surface and extract topographic data from stereo aerial photographs (Birdseye, 1940). With the integration of fundamental principles of photogrammetry with powerful algorithms from the computer vision community, collections of overlapping images can be automatically processed to quickly extract the relative 3D coordinates of millions of surface points (Lowe, 2004). Therefore, the only specialized resource required for the acquisition of 3D data through photogrammetric techniques is accessible and suitable software which depends on computer skills and requirements, and is available through both commercial and open-source alternatives. Among the free open-source commercial software that can easily be found and are user-friendly include PhotoScan, Acute3D, PhotoModeler, and 3DF Zephyr Pro.

The basic principle of photogrammetric entails the possible calculation of unique three-dimensional (3D) location of a set of given points from two overlapping photographs, relative to the cameras. In 'normal' photogrammetry which has evolved through surveying, remote sensing communities, and engineering, early estimations are usually derived by providing additional control data, such as the positions of known control points in images, prior to processing. This procedure permits error estimations (e.g., the accuracy of the control measurements) and a real-world coordinate system to be placed from the outset.

For rock slope discontinuity extraction, there are a few remote sensing techniques being developed and commercialized at the moment, such as 3D laser scanning or Structure from Motion (SfM) (Abellan *et al*., 2016). SfM technique allows the acquisition of millions of points of a surface with high accuracy, and the surface of a rock slope is digitalized using this dataset. As this dataset represents the surface of the rock slope, it may allow the identification and extraction of the existing discontinuity sets, its orientations, the normal spacing, the persistence and the roughness, as well as if the point cloud has enough quality (Riquelme *et al*., 2018). At this current moment, only discontinuity orientation and dip direction information can be extracted using this software (Riquelme *et al*., 2018).

Other method of identifying rock geological structures is 3D laser scanning, using instrument such as Terrestrial Laser Scanner (TLS). It allows high speed acquisition of coordinates (X, Y, and Z) of points of a surface (more than 222,000 measurements per second) from a considerable distance (up to 6,000 m). However, the cost of data acquisition of this instrument is currently expensive. TLS needs the use of a specific high specification computer to run all the analysis needed. In contrast, SfM only requires the use of a regular digital camera and a computer to process all digital photographs, but its precision is only limited by the camera resolution (James & Robson, 2012). Overall, this technique is much cheaper than TLS and is more suitable for educational sector.

This study focuses on the extraction of the discontinuity data sets of rock slope in an open pit quarry using 3D point clouds, obtained using the SfM technique. Unmanned Aerial Vehicle (UAV) was used to capture photos required for this technique. UAV method has been widely used for photogrammetric mapping of geological structures (Vasuki *et al*., 2014).

STUDY AREA

The study area covers the land of Hume Cement Quarry Sdn. Bhd. which is located in Gopeng, Perak at latitude of 4°23' North and longitude of 101°5' East. Figure 1 shows the location of the study area covering the central part of Peninsula Malaysia. The land of the quarry is geologically formed on the north part of Kinta Valley which represents various forms of limestone formation. Most of the limestone formation in Malaysia involves the process of karstification which yields a complex tectonic structure (Zabidi *et al*., 2016). The study area also covers part of the Kanthan Limestone bedrock in Kinta Valley. Kanthan Limestone generally comprises of locally prominent host rocks such as phyllite, slate, shale, and sandstone. Locally, the Kanthan Limestone at the quarry site is predominantly made up of massive and thin-bedded varieties with grayish white and black carbonaceous patches/spots. Moreover, fine-grained

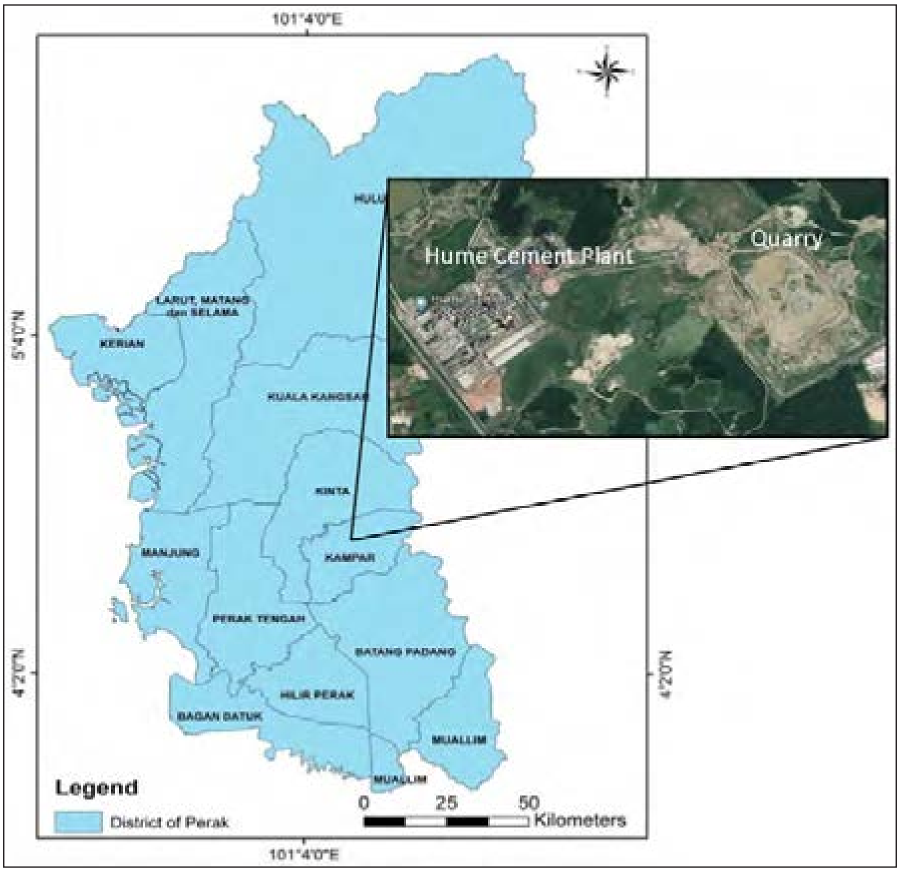

Figure 1: Location of the study area.

limestone is common and in places, it is intercalated or associated with carbonaceous (fissile) phyllite/schist. 4 m thick of massive fine-grained dolomite with creamy to pinkish white coloration was observed around the central part of the quarry area in the N-S direction. Structurally, this limestone formation is generally massive and interbedded in places as observed in many outcrops (Zabidi *et al*., 2016). Based on observation, Hume cement quarry rock faces are generally made up of yellow to yellowish brown, massive to highly bedded, and heavily jointed limestone rock strata.

METHODOLOGY

In order to produce 3D point clouds for the rock slope for this study, photos of the rock slope surfaces were taken via UAV method specifically by using DJI Phantom 4 Pro drone. The drone is built with a 20-megapixel camera, sufficient for photogrammetry method application as specified by certain recommendations (James & Robson, 2014). During the photos acquisition, overlapping photographs taken from different positions allow each feature in the overlapping area to be defined by a unique 3D position. After the evidence of the geological data was taken, the raw photos were processed and converted into a 3D model using the Agi PhotoScan software. Using this software, the raw photos were required to be primarily aligned before the location marker coordinates were placed. Following this, dense cloud was produced and the mesh and orthophoto were retrieved for further analysis.

Figure 2 shows the rock slope of the study area in 3D model. Upon performing a photogrammetry, it is recommended to test the quality of the model in terms of accuracy to emphasize more on the detailed analysis related to the coordinates of the model. Considering that a photogrammetry requires users to read the point cloud produced from photogrammetry method, users have to be precise in order to acquire accurate data and results.

After building the 3D model, analysis was carried out by analyzing the discontinuities set on the rock mass model generated by Discontinuities Set Extractor program (DSE) in MatLab. The input of this method is the 3D point clouds whereby each point has previously been classified by an assignment to a discontinuity set and to an aggregation of a point belonging to the same discontinuity plane, termed as a cluster. DSE is developed to calculate the cluster plane discontinuity set orientation with the best fitting plane (Riquelme *et al*., 2015).

Figure 3 shows the discontinuity plane set extracted from DSE program in MatLab. In order to visualize the discontinuities plane, Cloud Compare software was used.

Figure 2: Modeled study area by Agisoft Photo Scan.

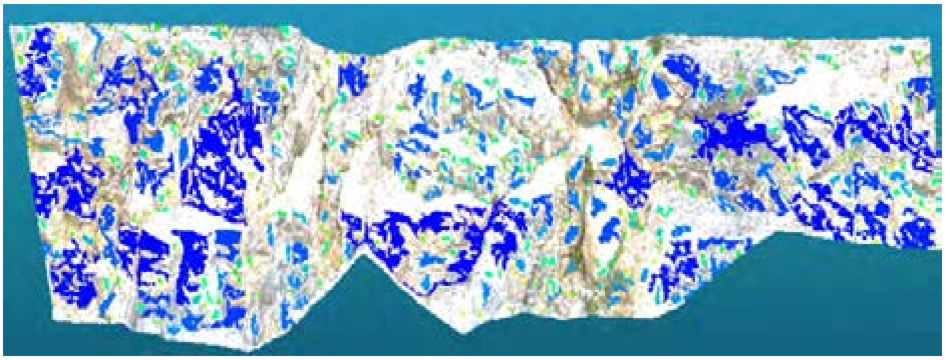

Figure 3: Example of discontinuity joint set (DS4) generated from DSE program and Cloud Compare.

Figure 4: The studied rock slope.

Manual mapping was carried out at the rock slope within 55 m length and 15 m height below the ramp road to pit, prior to results verification from the 3D point cloud analysis. The rock slope is as shown in Figure 4. Then, the dip and dip direction of the rock slope face was taken using clinometer instrument and was recorded in a data sheet. Scan line mapping technique was also employed to identify several requirements for Rock Mass Rating (RMR) analysis such as the condition of ground water, the spacing of the discontinuities, surface condition, location sketching, and also rock quality designation (RQD) value.

RESULTS

Based on the analysis from DSE program, ten discontinuity sets labeled as DS1 to DS10 were found at the rock slope. Table 1 shows the results from the DSE program. According to Table 1, DS1 is considered as the major discontinuity on the rock slope with the highest

Table 1: Results from photogrammetry mapping.

Discontinuity Joint Set	Dip Direction (°)	Dip (°)	Number of Cluster	Number of Points	Density	%
DS1	237.52	34.49	495	430294	4.0755	31.79
DS2	241.26	80.17	876	252696	0.9131	18.69
DS3	65.32	88.21	597	175798	0.6382	13.00
DS4	170.31	89.44	145	47771	0.4902	3.55
DS5	195.75	87.94	707	41223	0.3743	3.11
DS6	28.49	86.95	829	94509	0.3528	7.03
DS7	185.19	76.54	583	80926	0.2802	6.00
DS8	4.18	88.77	295	27113	0.2497	2.02
DS9	33.11	66.35	442	42415	0.2432	3.15
DS10	321.01	65.5	217	49348	0.1893	3.69

percentage of points (31.79%) oriented at 237.52° and 34.49° dip-dip direction. Furthermore, the pole density plot for DS1 as portrayed in Figure 5 compliments the result in Table 1.

Figure 6 shows the Rosette plot for the major direction of discontinuities from both photogrammetry and scanline mapping. The most dominant direction is N330° - N340° on NNW-SSE. Meanwhile, the least dominant discontinuities orientation occurred in the E-W direction at N080° - N090°. The main difference between both Rosette diagrams is the quantity of discontinuity set extracted. Photogrammetry mapping produces a larger number of orientations of discontinuity clusters compared to scanline mapping technique. Photogrammetry could simply extract more data from the rock slope including its orientation, direction, and dip direction. However, in terms of direction of the major plane of discontinuities, both techniques demonstrated identical direction comparable to one another.

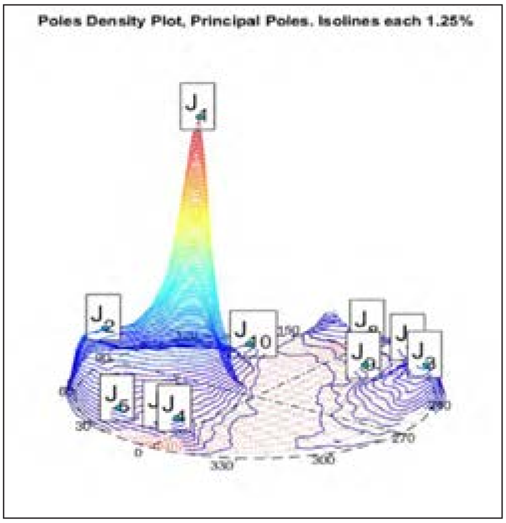

Figure 5: Pole density plot of ten joints set of discontinuity extracted from DSE program.

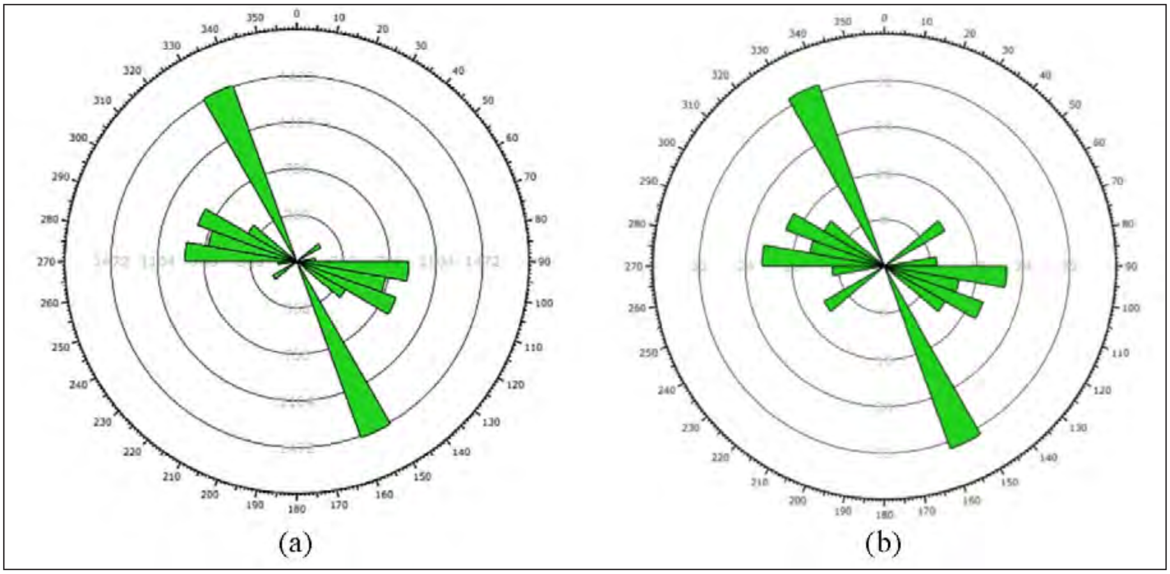

Figure 6: (a) Rosette plot by photogrammetry mapping, (b) Rosette plot by scanline mapping.

CONCLUSION

The main goal of the present work is to develop a workflow for extracting discontinuity sets using photogrammetry or SfM method. Besides, a few steps were considered in producing more accurate results which were then compared with manual scanline mapping. It was found that the methodology implemented has yielded reliable results. This method also provides safer, faster, and fewer bias outcomes by providing a good idea on the general discontinuity system at rock slope faces. However, several issues and limitations are present in this method. Firstly, the methodology only presents data on the most frequent plane orientation, exclusive of other characteristics information such as spacing, roughness, and persistence. These characteristics are important for a better understanding on the stability and quality of rock masses. Other than that, this workflow is nowhere from a complete automation, since several support programs are needed (Agisoft, MATLAB®, and Cloud Compare). A combination of all of the software into one complete software is deemed more practical for this method. It is safe to say that photogrammetry is a reliable technique for discontinuity mapping and analysis. Nonetheless, further study to automate the mapping process focusing on the reliability of the results is recommended to be done. The results can also be used to directly build a 3D numerical model of a rock mass.

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Geoscience activities amid the Covid-19 pandemic – opportunities for cross-discipline learning and knowledge-sharing

Mazlan Madon

Immediate Past-President, Geological Society of Malaysia and Adjunct Professor,
Geology Department, Universiti Malaya, Malaysia
Email address: mazlan.madon@gmail.com

Abstract: The Covid-19 global pandemic is affecting millions of people all over the world. Since the outbreak began daily lives and livelihoods have had to adjust to the "new normal": wearing face masks, social distancing, and restrictions on non-essential travel. Despite these lockdown rules, with available technologies, geoscience activities continued via virtual lectures, meetings and seminars. These creative ways of working offer the possibilities and opportunities for cross-discipline learning and knowledge-sharing during the pandemic and beyond.

Keywords: geoscience, Covid-19, pandemic, virtual meetings, virtual field trips

INTRODUCTION

For Malaysians, the year 2020 turned out to be an historic one on many fronts, not just politically (a sudden change of government happened just two years after the General Election in 2018), but also socially and economically due to the far-reaching effects of the Covid-19 global pandemic. Since this is an historic moment in time, probably in our lifetimes, it should not be left unnoticed and warranted at least a mention in our Warta. The pandemic has effected people all over the world in many ways, and geoscience in general and GSM in particular have had to adapt and adjust to the unfolding, and still ongoing, situation. The brief note is a personal take on the events during the months of early 2020 since the pandemic began.

THE COVID-19 PANDEMIC

The first half of the year 2020 had been a tumultuous time for the entire world. No one saw it coming. The Covid-19 ("Coronavirus disease 2019" pandemic, which is caused by the coronavirus SARS-CoV-2)[1] hit us so fast that by April 2020, most countries of the world were put under some sort of restriction to "normal" life, from banning public gatherings to total lockdown. The Malaysian government implemented the Movement Control Order (MCO) on 18 March 2020, which restricted business and daily activities to only "essential" services. People are asked to wear face masks and follow the rules of social distancing – keep a distance of at least 1 metre from each other. Domestic and overseas travel were not allowed as all borders were closed. The MCO was put into effect just two days of my arrival back from New York after completing another two-month session at the United Nations headquarters, and as the virus was spreading in the US through the months of April and May, the United Nations postponed all in-person meetings at its headquarters and moved them online. At the time of my departure in mid-March the daily average number of confirmed new cases of Covid-19 in New York City was about 50. A month later, while I was at home in Kuala Lumpur, I heard on the news that daily cases in New York City had increased to more than 5000. At the time of writing this article the number of Covid-19 cases for the entire world is almost 18.5 million, with over 4.77 million cases in the United States alone (Figure 1). With the global death toll at over 700,000 as of 5 August 2020, Covid-19 is among the deadliest pandemics of the 20th and 21st century.

Malaysia has had its own challenges in fighting Covid-19 but thanks to dedicated frontline health-care workers (doctors and nurses) and the Malaysian Health Department, with the cooperation of the Malaysian public on the whole, our country managed to "flatten the curve" by the end of May, bringing down the rate of Covid-19 infections under control (Figure 2). At the time of writing (5 August), the number of cases nationwide stood at 9002, of which 8684 (96.5%) have recovered while the number of deaths is 125. It is hoped that the recent spate (at the

[1] WHO website, https://www.who.int/emergencies/diseases/novel-coronavirus-2019/technical-guidance/naming-the-coronavirus-disease-(covid-2019)-and-the-virus-that-causes-it accessed 25 July 2020.

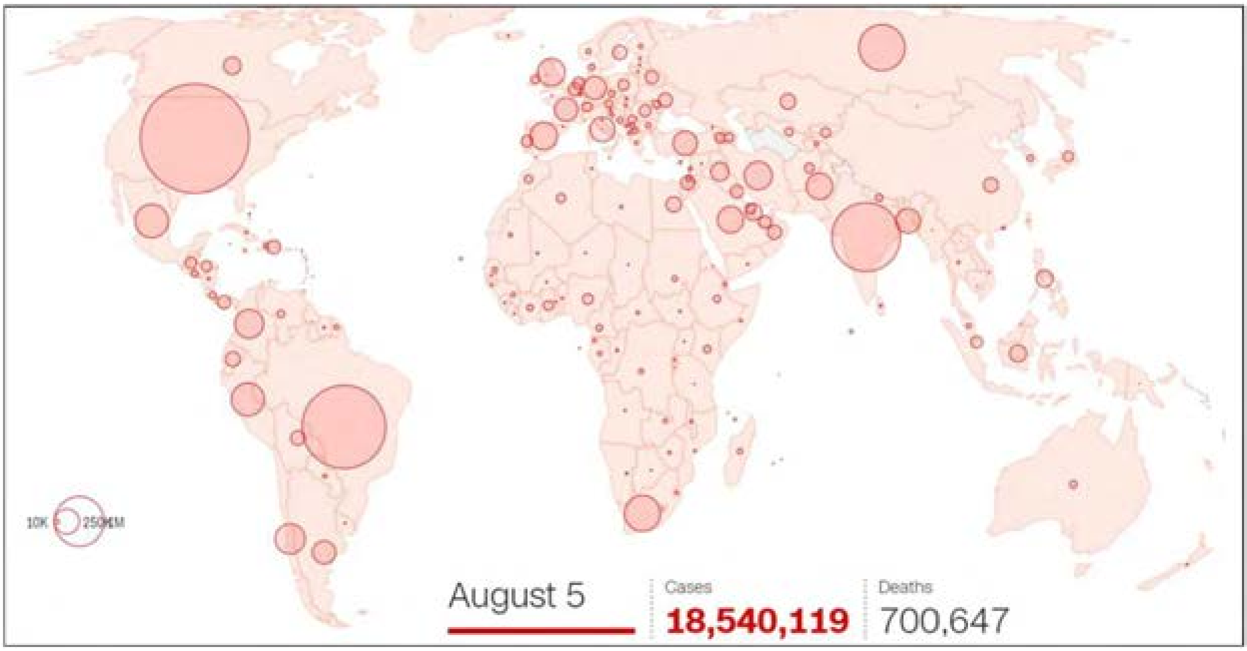

Figure 1: Global Covid-19 cases as at 5 August 2020. Source: CNN. https://edition.cnn.com/interactive/2020/health/coronavirus-maps-and-cases/ accessed 5 August 2020.

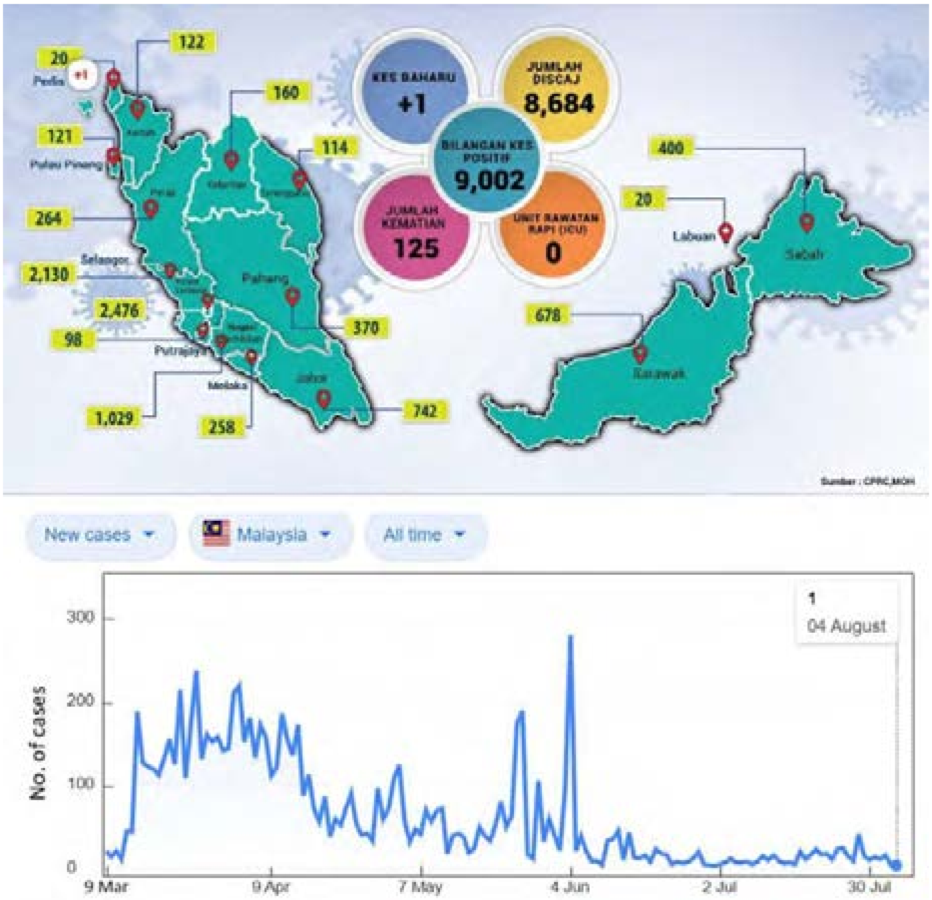

Figure 2: Cases of Covid-19 in Malaysia. Top: Number of cases by State at 5 August 2020. Source: Ministry of Health, Malaysia. Bottom: Daily reported cases as at 4 August 2020 compiled by Google.

end July) of new clusters of infections can be managed and contained and that citizens remain cautious and not to take for granted the risks with going back to "normalcy" too quickly, while the global situation seems to suggest that the pandemic is far from over.

VIRTUAL MEETINGS

The effect of movement restrictions and lockdown has had a definite long-lasting impact on ordinary citizens' daily life, schools, universities, and businesses. Geoscience is not spared from Covid-19. Due to the restrictions on public gatherings and rules on social distancing, in-person meetings and conferences could not be held. The planned National Geoscience Conference (NGC) 2020 scheduled for April 2020 had to be postponed to 2021. The annually held NGC was to be held in conjunction with the 50th anniversary celebrations of Universiti Kebangsaan Malaysia's geology department, but alas that too had been affected. Fortunately, the geology alumni of UKM were able to connect online to commemorate the 1970 founding of their beloved alma mater.

The Geological Society of Malaysia (GSM), for the first time in its 53-year history and thanks to technology, also had to resort to conducting its meetings online, including council meetings and the 53rd Annual General Meeting (AGM) (Figure 3). The inability to meet in person did not hamper our commitment and passion to fulfil our responsibilities to the Society. In fact, online meetings may be here to stay, with or without Covid. Virtual meetings give the participants more flexibility to join the meetings from wherever they choose to be, without having to rush through the afternoon traffic on a Friday afternoon to the meeting venue, normally at the Geology Department, Universiti Malaya. Perhaps, in the future, meetings could be conducted in a "hybrid" format in which normal in-person meetings are done with some members, especially those in remote locations, join in via the internet.

Besides GSM, other geoscience institutions have also adapted to the pandemic by holding remote meetings and virtual seminars (webinars). Examples include the Institute of Geology Malaysia (IGM) newly launched online monthly webinar on Coastal and Marine Geology and CCOP's online conference on the Geology of SE Asia (Figure 4). Technical talks such as these can now be held and attended from anywhere without the need to travel. In the past, travelling to a seminar venue was often used as a reason why GSM technical talks held at University departments could not attract industry professionals, especially from the oil and gas sector. This excuse may not be tenable anymore if the seminar is done by virtual means. Although virtual meetings may not totally replace in-person meetings and conferences, the experiences during this pandemic has opened a new possibility for participation via remote means and thus widening the target audience.

Due to the MCO, Universities all over the world, not only in Malaysia, have had to shift their classes online. In a very resourceful article published in Geology Today (vol. 36, No. 3, May–June 2020) Professor Chris King at Keele University, UK, gives some ideas on the variety of platforms for geoscience teaching that are available through today's technology, which include online textbook ("Exploring Geoscience Across the Globe"[2]), podcasts and TV geology programmes (King, 2020).

VIRTUAL FIELD TRIPS

We can only empathise with those geoscientists working on field projects (including students, PhD especially) who have limited time and resources to complete their thesis, and the suddenly imposed lockdown prevented them from going to the field. This may affect their work, especially if it involves sampling and measurements. It may be less problematic for undergraduates, although they would miss the opportunity to be able to see rocks in the field for themselves. As we all know, field trips are an important part of the geology curriculum, more so in the age of the "desktop geology" where geologists may be spending a large chunk of their careers without ever stepping on a real rock!

Creative ways in geoscience teaching were able to bring outcrops to the classroom during Covid-19 lockdown. Luckily for some, there are "virtual field trips", which have become more and more popular as an alternative way of bringing outcrops to the office or classroom. The Covid-19 pandemic may have given the proponents of virtual learning, particularly virtual field trips, a much-needed boost towards promoting this technology platform to schools and industries alike. Online classes include virtual field courses developed on the Google Earth platform where virtual outcrops are embedded with explanatory text for the student to conduct the field study in their own time and pace[3]. Imperial College London responded to Covid-19 by implementing remote learning for its MSc Petroleum Geoscience by taking students on a simulated overseas trip to the Pyrenees.[4]

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[2] This is a free-to-use textbook available as a downloadable pdf file, to be found at http://www.igeoscied.org/wp-content/uploads/2019/12/Geotextbook_Dec_2019.pdf.

[3] "Geology of Yosemite Valley," a 43-stop Google Earth virtual tour https://www.sciencemag.org/news/2020/07/during-pandemic-students-do-field-and-lab-work-without-leaving-home

[4] Imperial geoscientists complete UK's first MSc virtual field trip, https://www.imperial.ac.uk/news/196961/imperial-geoscientists-complete-uks-first-msc/ accessed 25 July 2020.

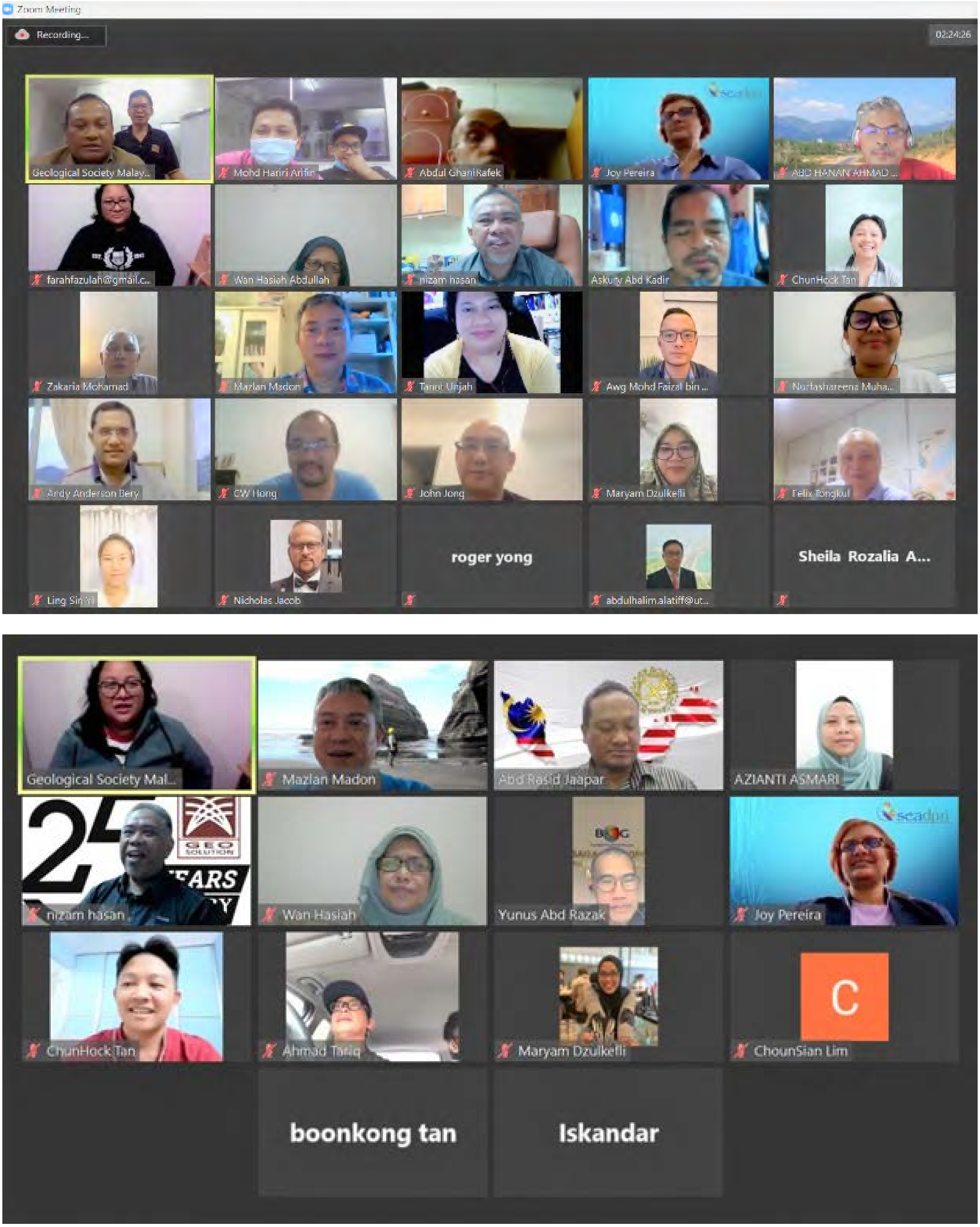

Figure 3: Screenshots of online meetings via Zoom™. Top: 53rd AGM meeting held on 26 June 2020. Bottom: First council meeting for the term 2020/21 held on 24 July 2020.

Figure 4: Due to Covid-19 social distancing rules, seminars were being conducted online via remote applications such as Zoom™. These are examples of seminars held during the pandemic.

In 2008 I saw the value of virtual field trips as an invaluable tool for geoscience learning and, with my colleagues at PETRONAS Research, tried to capture on video some of the good outcrops in Kota Kinabalu area and Labuan (Figure 5). Now, I wish we had captured all the Malaysian outcrops (this was before the age of smart phones, so we used the videocam – the standard equipment at the time). Hopefully, with the the latest available technologies (e.g., LIDAR and VR or Virtual Reality) more could be done to produce virtual field trips which would benefit students and geoscientists for generations to come. It is not too late and perhaps, this could potentially be a project for societies like GSM and interested collaborators from industry and academia.

SOME LEARNINGS DURING THE COVID-19 PANDEMIC

Despite the difficulties faced by geoscientists due to the restrictions imposed to fight the spread of Covid-19, geoscience research and Earth Sciences in general are still progressing in many parts of the world. A quick glance through recent articles on the effects of Covid-19 pandemic on scientific research, and geoscience research in particular, revealed some very interesting results. According to one article, Covid-19 has already affected the accuracy of weather forecasting due to the lack of aircraft observations especially over areas with normally busy air traffic like southeast China and the US (Chen, 2020).

There is also the unintended but welcomed effect of lockdowns – reduced air pollution. Lockdowns meant that factories and transport systems were shut down, thus reducing emissions due to anthropogenic activities. A paper by Shi & Brasseur (2020) showed that, after the lockdown due to the COVID-19 outbreak of early 2020, surface measurements made at more than 800 monitoring stations show that the mean levels of $PM_{2.5}$ and NO_2 in northern China have decreased by approximately 35% and 60%, respectively. These are short-term effects which have also been observed in other cities known to have high levels of air pollution, e.g. New Delhi and Seoul[5]. In fact,

[5] The link between air pollution and COVID-19 deaths https://www.weforum.org/agenda/2020/04/link-between-air-pollution-covid-19-deaths-coronavirus-pandemic/ accessed 26 July 2020.

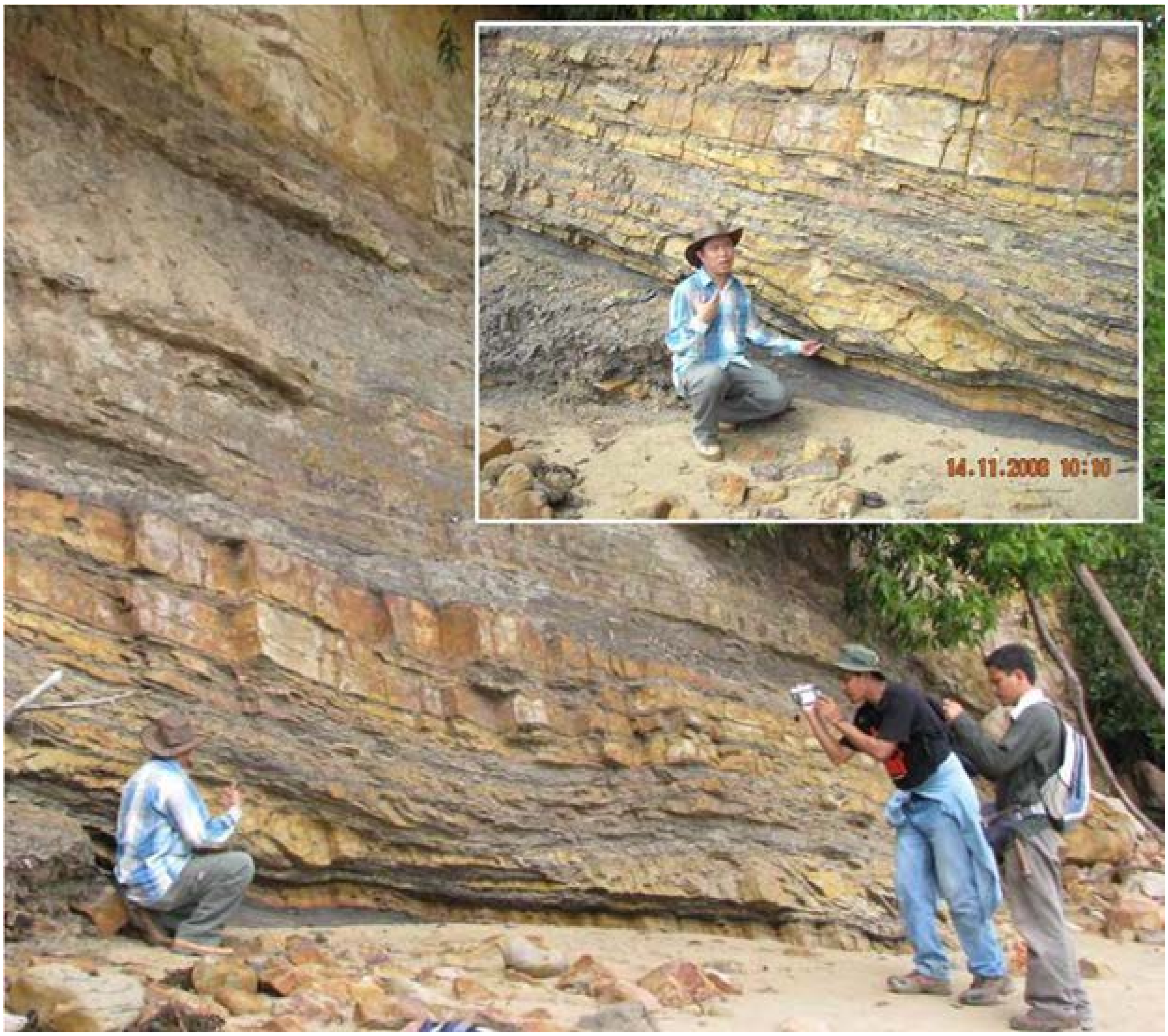

Figure 5: On location at Bethune Head in Labuan in 2008, shooting videos for virtual field trips, with former colleagues from PETRONAS Research, Zainol Affendi Abu Bakar (centre, with videocam) and Hasnol Hady Ismail (right). Inset: view from Hasnol's camera.

the same was observed in the west coast of Peninsular Malaysia, from Pulau Pinang to Singapore (Figure 6) and has been quantitatively demonstrated (e.g., Kanniah *et al*., 2020) to reduced $PM_{2.5}$ by 30% and NO_2 by 60%. It should be noted, though, that ozone concentration had simultaneously increased by a factor 1.5–2.0, which seems to offset the reduction of $PM_{2.5}$ and NO_2 (Shi & Brasseur, 2020). The increased air quality, however, is a welcome effect since other studies have suggested a strong link between Covid-19 deaths and long-term exposure to air pollution (Ogen, 2020).

It may not be all bad news as seismologists would be delighted to learn that, according to a study published in Nature[6] (Lecocq *et al*., 2020), lockdowns imposed by countries globally have resulted in lower crustal background seismic noise – the "humming" vibrations in the earth crust due to human activities, such as transportation and machinery. It is said that such low levels of background noise is experience only briefly around Christmas. The reduction in background noise enables geophysicists to detect seismic activity in the earth's crust that would not have been detected under "normal" pre-pandemic level of background seismic noise, such as smaller earthquake events and volcanic activity.

Geoscientists who study earthquakes, tsunamis and volcano eruptions are attuned to scale of destruction to

[6] Coronavirus lockdowns have changed the way Earth moves. Nature 580, 176-177 (2020), doi: 10.1038/d41586-020-00965-x.

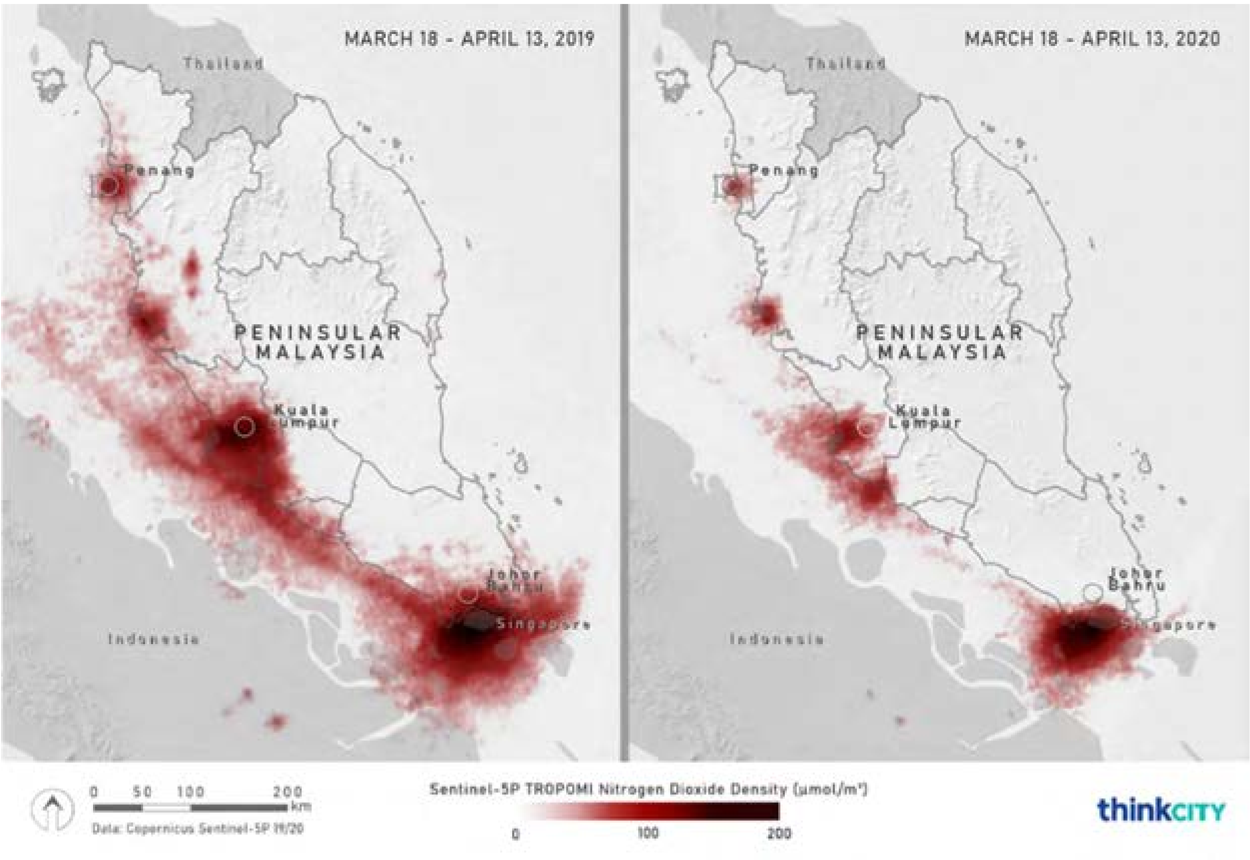

Figure 6: NO_2 concentration levels in the urbanised areas of Peninsular Malaysia during the period of 18 March – 13 April, 2019 (left) and the same period in 2020 (right). The maps were produced by Think City from spectrometry data obtained from Copernicus Sentinel-5P European Space Agency satellite., based on satellite data. https://thinkcity.com.my/nitrogen-dioxide-levels-decrease-due-to-mco/ accessed 26 July 2020.

human life and property these natural hazards can inflict. Amid the pandemic, some authors have suggested that there are lessons to be learned from geoscientists dealing with natural hazards could be applied in predicting and managing the spread of infectious diseases like Covid-19, as the scale in time and magnitude of the destruction of a pandemic are similar to those of geological disasters such as earthquakes or volcanic eruptions (see the review of natural disasters by Ritchie, 2014). Mark Quigley, associate professor of earthquake science at the University of Melbourne, draws some similarities between the Covid-19 outbreak and his experiences and knowledge of geological and meteorological disasters and suggested there may be ways one could learn from the different sciences to mitigate the effects of the pandemic. He suggested that concepts and best practices in disaster risk reduction (DRR) commonly employed by geoscientists in mitigating risks due to earth science phenomena such as earthquakes and tsunamis may be relevant to Covid-19 (e.g., social distancing, vulnerability of certain age groups, safe time to relax lockdown, etc). These ideas are discussed in Quigley *et al.* (2020).

CONCLUDING REMARKS

Despite the difficulties faced as a result of the restricted movements due to the Covid-19 pandemic, geoscientists (and undoubtedly, other scientists too) have remained positive and continued to carry out their activities in the best possible ways using the available technologies. As there is no telling when the situation can return to "normal", if at all, we have to be prepared to adapt and meet the challenges for the future of geoscientists and geoscience. Creative ways of geoscience communication and knowledge-sharing within the geoscience community as well as with other scientists should be encouraged and enhanced to forge a stronger and resilient science-based education and policy-making for the benefit of the society.

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Manuscript accepted 6 August 2020

PERSATUAN GEOLOGI MALAYSIA
GEOLOGICAL SOCIETY OF MALAYSIA

54th ANNUAL GENERAL MEETING & ANNUAL REPORT 2019

26th June 2020
via
ZOOM Online Meeting Platform

AGENDA

The Agenda for the Annual General Meeting is as follows:

1. Welcoming Address by the President for Session 2019/2020
2. Confirmation of Minutes of the 53rd AGM
3. Matters Arising
4. Annual Report for Session 2019/2020
    a. President's Report
    b. Secretary's Report (including Assistant Secretary's Report)
    c. Editor's Report
    d. Treasurer's Report
    e. Honorary Auditor's Report
    f. GSM Endowment Fund Report
5. Election of Honorary Auditor
6. Other Matters
    6.1 Formation of IGM-GSM Chapters for Sabah and Sarawak
    6.2 Affirmation of Upper Segama Sabah Jurassic and Triassic Granitic Rocks by Radiometric U-Pb Dates
7. Announcement of New Council for 2020/2021
8. Presidential Address for 2020/2021

PERSATUAN GEOLOGI MALAYSIA
GEOLOGICAL SOCIETY OF MALAYSIA (GSM)

MINUTES OF THE 53rd ANNUAL GENERAL MEETING

Date: 29th April 2019
Time: 2.30 p.m.
Venue: Persatuan Alumni Universiti Malaya (PAUM) Club House, Kuala Lumpur

Members Present:

1. Abd Rasid Jaapar
2. Abdul Ghani Rafek
3. Ahmad Nizam Hasan
4. Ahmad Said
5. Ahmad Tariq Ahmad Ziyad
6. Askury Abd Kadir
7. Cheang Kok Keong
8. Farah Fazulah Abdullah
9. Fateh Chand
10. Gan Lay Chin
11. Joy J. Pereira
12. Lee Chai Peng
13. Leong Khee Meng
14. Lim Choun Sian
15. Mazlan Madon
16. Mohammad Muqtada Ali Khan
17. Mohd Hariri Arifin
18. Nicholas Jacobs
19. Norazianti Asmari
20. S Paramananthan
21. Sia Hok Kiang
22. Tan Boon Kong
23. Wan Hasiah Abdullah
24. Yip Foo Weng
25. Yves Cheze
26. Zakaria Mohamad

1. Welcoming Address by the President for Session 2017/2018

Mr Abd Rasid Jaapar, the President of Geological Society of Malaysia acted as the Chairperson of the AGM and called the meeting to order at 2.30pm.

2. Adoption of Agenda

The Chairperson tabled the following agenda to the AGM for acceptance:

1. Welcoming Address by the President for Session 2018/2019
2. Confirmation of Minutes of the 52nd AGM held on the 27 April 2018
3. Matters Arising
4. Annual Report for Session 2018/2019
   a. President's Report
   b. Secretary's Report
   c. Editor's Report
   d. Treasurer's Report
   e. Honorary Auditor's Report
   f. GSM Endowment Fund Report
5. Election of Honorary Auditor
6. Other Matters
   a. GSM Digital Publications
   b. Meeting Allowances
   c. ASEAN Federation of Geoscience Organisastions
7. Announcement of New Council for 2019/2020
8. Presidential Address for 2019/2020

The agenda was unanimously accepted.

2. Confirmation of Minutes of the 52nd AGM held on the 27 April 2018

The Minutes of the 52nd AGM was tabled for confirmation.
Mr Tan Boon Kong proposed that the minutes be confirmed, seconded by Ms Farah Fazulah Andullah. The minutes were unanimously confirmed without any amendment.

3. Matters Arising (52nd AGM Minutes)

Matters Arising	Responses
[4f]. Recommendation from the Board of Trustees since 50th AGM (2016): Tax consultant for tax deductible status for GSM	• The matter will be highlighted in the agenda 4(f) Recommendation from the Board of Trustees in this meeting.
[7b]. The AGM proposed GSM to create a HD Tjia Award in honouring Prof Emeritus Tjia HD contribution.	• However, GSM Editorial Group is coming up with a plan for a manuscript to commemorate the late Prof. Tjia in an issue of the GSM Bulletin from multiple contributors. Prof Ibrahim has agreed to lead the initiative.
4a. i. CCOP ii. Paperless iii. BoG	The matter will be highlighted in agenda i. 4(a) President's report ii. 6(a) Matters Arising iii. 4(a) President's report
4b. i. Nomination of GSM Awards ii. Reprint of publication	i. Will be improved, the Council has tasked Vice President to this matter in next Council ii. No request so far
4c. i. Relation with PGCE ii. NGC sponsorship and overhead iii. Spend more on society's activities	i. On establish connection with Petronas, GSM Council Members had a meeting with the Vice President of Exploration, as in GSM President's report. ii. NGC – improving slowly iii. The Council is working towards it
4f. Recommendation from the Board of Trustees	• The matter will be highlighted in the agenda 4(f) Recommendation from the Board of Trustees in this meeting

No comment from members of AGM.

Action: Information

4. Annual Report for Session 2018/2019

a. President's Report

Abd Rasid Jaapar tabled the President's Report (Appendix A).
The AGM discussed the following matters:

- On the proposal to turn NGC into GSM-IGM Geoscience Conference: Prof. Joy Pereira cautioned that it may downgrade the prestige and trademark of the NGC and suggested to allocate an IGM special thematic session in NGC. Dr. Mazlan Madon suggested GSM and IGM should have more joint activities.
- Dr. Abdul Ghani Rafek expressed his observation on GSM has lesser activities with USM (geophysics joint seminar). The meeting highlighted the need to revive and actively find GSM counterparts at universities.
- Dato' Sia proposed GSM to lead activities in geological excursion and research, giving example on new rock exposures of roadcut and should seize the opportunity.
- Datuk Fateh and Dr Paramananthan proposed GSM to carry out a compilation or databases (titles, abstract) of geoscience-related thesis for Malaysian universities.

Action: Incoming Council

Dr Paramananthan proposed that the President's Report to be accepted, seconded by Datuk Fateh Chand.

b. Secretary's Report

Lim Choun Sian tabled the Secretary's Report and Assistant Secretary's Report was presented by Mr. Askury Abd Kadir (Appendix A).

The AGM discussed the following matters:

- The President's plan to increase membership: The Council is working on membership database to get back old members and promoting student members to continue full membership.
- Dr Gan suggested GSM to engage and "in touch" with old members in its future activities.
- The AGM also asked to relook at the activeness of Working Groups, recommended future Working Group activities to be listed from reports of their respective working groups' Chairs.

Action: Incoming Council & Working Groups Chairs

Ms Farah Fazulah proposed that the Secretary's Report to be accepted, seconded by Dato' Zakaria.
Dr Abdul Ghani Rafek proposed that the Assistant Secretary's Report to be accepted, seconded by Dr Mohammad Muqtada.

c. Editor's Report

Wan Hasiah Abdullah tabled the Editor's Report (Appendix A).

The AGM discussed the following matters:

- Some members expressed that some form of fees should be charged for publication. The overall's view, GSM publication will be maintained as open access and should seek funding through sponsorship or advertisement.

Action: Incoming Council

Datuk Fateh Chand proposed that the Editor's Report to be accepted, seconded by Dr Paramananthan.

d. Treasurer's Report

Ahmad Nizam Hasan tabled the Treasurer's and Honorary Auditor's Report, see 4(e) (Appendix A).

e. Honorary Auditor's Reports

The AGM discussed the following matters:

- Dr Gan proposed the Council to use some money to promote GSM.
- Dr Abdul Ghani Rafek proposed the Council should allocate working capital for Working Groups. The meeting's view, active working groups (the Chairs) should come up with their budget plan at the start of the Council year.
- The AGM agreed to RM1,000 increment of Ms Anna Lee's monthly allowance.

Action: Incoming Council

The AGM unanimously accepted the Treasurer's and Honorary Auditor's Report.

f. GSM Endowment Fund Report

Datuk Fateh Chand, Chairman in Board of Trustees of the GSM Endowment Fund, tabled the GSM Endowment Fund Report and Recommendations from the Board of Trustees (Appendix A).

Mr Askury proposed that report and recommendations from the Board of Trustees to be accepted by AGM, Dr Paramananthan seconded.

Action: Incoming Council

6. Election of Honorary Auditor

Ahmad Nizam Hasan proposed to continue appointing S.F. Lee & Co as the Honorary Auditor.

The AGM unanimously agreed to the appointment.

7. Other Matters:

Matters and Responses:

a. GSM Digital Publications

The AGM approved, with immediate effect, to publish (Warta and Bulletin of the Geological Society of Malaysia) and distribute to members in full digital format.

Action: Incoming Council

b. Meeting Allowances

The AGM approved travel reimbursement to GSM Council Meetings up to RM100, using the rates in government travel claim form.

Action: Incoming Council

c. ASEAN Federation of Geoscience Organisastions (AFGO)

The AGM recommended the AFGO initiative to be carried out under the GSM-IGM joint committee.

Action: Incoming Council

8. Announcement of New Council for 2019/2020

Nomination Committee chaired by Dr Mazlan Madon, certified by Prof. Azman Abd Ghani and Assoc. Prof. Dr Ng Tham Fatt.

The Council for 2019/2020:

President	: Mr. Abd. Rasid Jaapar (Geomapping Technology)
Vice-President	: Mr. Askury Abd Kadir (Consultant)
Immediate Past President	: Dr. Mazlan Madon (Consultant)
Secretary	: Mr. Lim Choun Sian (UKM)
Assistant Secretary	: Ms. Farah Fazulah Abdullah (Carigali Hess)
Treasurer	: Mr. Ahmad Nizam Hasan (GeoSolution Resources)
Editor	: Prof. Dr. Wan Hasiah Abdullah (UM)

Councillors 2018/2019:

Mr. Ahmad Tariq Ahmad Ziyad (Orogenic Resources Bhd)
Dr. Mohd Hariri Arifin (UKM)
Mr. Nicholas Jacob (JMG)
Ms. Norazianti Asmari (GDS Sdn Bhd)

Councillors 2019/2021:

Prof. Joy Jacqueline Pereira (SEADPRI-UKM)
Dr. Nur Iskandar Taib (UM)
Mr. Tan Boon Kong (Consultant)
Dato' Yunus Abdul Razak (SEADPRI-UKM)

9. Presidential Address for 2019/2020

The President, Abd Rasid Jaapar expressed that it is a great honour for him to be re-elected to serve as the President and followed by delivering his inaugural speech. He pledged that he and the new Council would try their best to serve for the good of the Society.

The AGM adjourned at 5:00 pm.

LIM CHOUN SIAN
Secretary 2018/2019
29 April 2019

Note:

Appendix A is the whole set document distributed during the AGM on 29 April 2019, not included in this document.

APPENDIX A

PRESIDENT'S REPORT

1.0) Introduction

The Geological Society of Malaysia (GSM) has sustained its objective of actively promoting the advancement of the geological sciences in the country and the region. Over the past year, GSM continued with activities that were designed to strengthen the capacity of geoscientists and had embarked on initiatives to formalise collaborations and alliances with key institutions within the geoscience fraternity.

2.0) The IGM-GSM Joint Committee

The IGM-GSM Joint Committee had met 2 times over the year. The Joint Committee will continue to oversee the collaboration between the two institutions, especially on capacity building, outreach & promotion, geoscience policy and quality geoscience education in Malaysia. Recently IGM-GSM JC has agreed to form IGM-GSM Sabah Branch and IGM-GSM Sarawak Branch to coordinate and organise activities in respective region. With that also, GSM will dissolve all Regional Representative positions.

IGM-GSM Geoscience Business Working Group is now has evolve to be an independent association be itself called, Malaysian Geoscience Consultants and Services Association (MyGeo). The members are any company or an organisation actively involved with the business of geoscience. The protem committee has been set up together with the constitution and has been accepted by protem members.

3.0) Promotion and Collaborations

GSM has signed MOU with Universiti Malaysia Kelantan (UMK) on 30th May 2019 and with University of Malaya (UM) on 8th October 2019. GSM also has signed Letter of Undertaking with Universiti Malaysia Sabah (UMS) to initiate MOU during the NGC2019. MOU with Universiti Kebangsaan Malaysia (UKM) is in the pipeline.

GSM has commissioned the Geological Student Club of UMS to be the first GSM Students Club' @ UMS. All GSM Students Club will receive financial support of RM2,000 per year to organise activities and events related to advancement of geoscience knowledge and the promotion of geoscience. Trust GSM can tap future members and future leaders at very early stage even before students enter the real-world challenge.

The President and/or appointed Council Members will continue to visit as many geological departments in local universities possible throughout the year. The visit to Universiti Sains Malaysia and Curtin University, Sarawak has yet to be materialised.

The President and Treasurer as GSM representatives attended the 55th CCOP Annual Session from 3rd November to 9th November 2019 in Chiangmai, Thailand. GSM agreed to remain as observer status in CCOP and be part of Malaysian delegations. The Director-General of Jabatan Mineral dan Geosains (JMG), the current chair of the CCOP (Coordinating Committee for Geoscience Programmes in East and Southeast Asia, based in Bangkok, Thailand), has accepted that GSM should be part of Malaysian delegations. Trust our members can benefit from the many events organised by CCOP.

4.0) Major Activities and Participations

a) National Geoscience Conference (NGC)

The 32nd edition of National Geoscience Conference & Exhibition 2019 (NGC2019) with the theme 'Geosciences for the Earth Sustainability' was successfully co-organised with the Universiti Malaysia Sabah (UMS) and Jabatan Mineral dan Geosains Sabah between 1st and 3rd October 2019 at The Palace Hotel, Kota Kinabalu, Sabah. The NGC2019 had also provided exhibition booths for exhibitors to promote their products and services. The pre-conference Workshop on the Importance of Geosciences for Sustainable Development on 30th September 2019 with participants from various government agencies, corporates and learned organisations was a success. Most participants looked forward to similar event to be organised more frequent in Sabah.

The 33rd National Geoscience Conference & Exhibition 2020 (NGC2020) which was initially planned between 1st and 4th September 2020 in UNITEN was postponed to between 23rd and 26th November 2020. After observing the uncertainty Covid-19 pandemic, the Council and Committee agreed to re-schedule the 33rd NGC to be NGC2021 and will be held between 5th and 11th April 2021 in Tanera Hotel, Bandar Baru Bangi, Selangor. It will be a week-long event as part of National Geoscience Week in conjunction with Geologists Day celebration on 4th April 2021 and Earth Day on 22nd April 2021. For the first time, GSM with collaboration with JMG, IGM, BOG and MyGEO may organise National Geoscience Award Night on 5th April 2021.

b) Field Excursions

I will maintain my last year use of old adage that ‘the best geologist is (the one) who has seen the most geology’ (Read, 1940). Unfortunately, due to Covid-19 Pandemic, most of planned field excursion activities has to be postponed or cancelled. GSM will pursue further on similar activities like this even to other countries.

c) GEOSEA

GSM continued to be the secretariat for the Regional Congress on Geology, Minerals and Energy Resources of Southeast Asian (GEOSEA). The 16th edition of the Congress or GEOSEAXVI will be hosted by the Geological Society of the Philippines (GSP). Originally scheduled from 7th to 9th December 2020 in Manila, the Philippines with the theme of ‘5 years after ASEAN integration: Milestones, Challenges and Perspectives for Geoscientists has been postponed to December 2021 due to Covid-19 Pandemic. GSM has proposed the following and received positive feedback from country members:

i) Formation of ASEAN Federation of Geoscience Organisation (AFGEO) through MOU as well as roadmap to ASEAN Register of Professional Geologists. Hopefully, an official MOU signing ceremony on the formation of AFGEO by all country members can be done in 2021 in Manila.

ii) Change the name of Regional Congress on Geology, Minerals and Energy Resources of Southeast Asian to ‘Regional Geoscience Congress of Southeast Asia’ with the same abbreviation of GEOSEA. GSM would like to encourage our members to participate the GEOSEAXVI.

5.0) Publications

GSM has started with e-publication initiative. Trust this will help improving our financial status greatly. We are now moving towards complete paperless publications depending on authority and legal requirements.

The Editorial Committee will continue to improve and upgrade our Warta Geologi which is published three times a year now to be Scorpus-indexed. The Bulletin of the Geological Society of Malaysia, consistently published twice a year now and on the right track to achieve ISI-index status. The index will ensure our Bulletin to become one of the sought-after publications in this region by researchers and readers.

I would like to thank Editorial Committee lead by Prof Dr Wan Hasiah as Editor, Associate Professor Dr Ng Tham Fatt as the Managing Editor for the Bulletin and Puan Aida as the Editorial Executive for their tireless efforts.

6.0) Membership

As my earlier target that GSM to achieve 1,000 memberships by the end of 2020, I am still optimistic provided I have sufficient support from respective council members. Nevertheless, due to Covid-19 Pandemic, I may differ my target to June 2021.

7.0) Financial and/or Asset Management

Same as previous year, I strongly urge the members of GSM to support on the improvement on the management of GSM. We need to manage GSM professionally like a business entity, with more full-time staffs. GSM has re-vamp its current website to be more interactive with members and incorporate an on-line payment system, on-line technical papers submission, etc. Further enhancement is still needed as ongoing process.

8.0) Concluding Remarks

We would like to thank all the outgoing council members for the contributions; to all members for ideas and supports. Thanks to all organising chairs of all events, working group chairs and regional representatives. Last but not least, a big thank to the one and only secretariat member, Ms Anna Lee for another excellent year of contribution.

As a final remark, I would like to see GSM, IGM, BOG and new comer, MyGeo and of course, under the umbrella of JMG should come together to develop a solid National Geoscience Policy/Agenda, as well as awareness or outreach to public on the importance of geoscience for nation building.

ABD RASID JAAPAR
President 2019/2020
Geological Society of Malaysia

SECRETARY'S REPORT 2019/2020

On behalf of the members of the Council of the Geological Society of Malaysia (GSM), it is my pleasure to present the Secretary's Report for the session 2019/2020.

Society structure

The Society's stakeholders are the members of the Society led by an elected Council. The Council's main functions are to set directions to promote the advancement of geosciences, endorse activities and provide guidance for the execution of the activities of the Society.

The Council is supported by 9 Working Groups, 6 Regional Representatives and an Editorial Committee (formerly known as Editorial Group). The Working Groups were increased from 6 to 9 in the year 2019, with addition of Working Groups on International Collaboration; Quaternary & Marine Geology; and Hydrogeology.

The Council

The Council for the Geological Society of Malaysia for 2019/2020 session resumed their office after the 53rd AGM on the 29 April 2019.

Council for 2019/2020

Upon the closing of nominations, only single nominations were received respectively for the positions of President, Vice President, Secretary, Treasurer, Assistant Secretary, Editor and Councillors.

The Council for 2018/2019:

President	:	Mr. Abd Rasid Jaapar (Geomapping Technology)
Vice-President	:	Askury Abd Kadir (Consultant)
Immediate Past President	:	Dr. Mazlan Madon (Consultant)
Secretary	:	Dr. Lim Choun Sian (UKM)
Assistant Secretary	:	Ms. Farah Fazulah Abdullah (Carigali Hess)
Treasurer	:	Mr. Ahmad Nizam Hasan (GeoSolution Resources)
Editor	:	Prof. Dr. Wan Hasiah Abdullah (UM)

Councillors 2018-2020:

Mr. Ahmad Tariq Ahmad Ziyad (Orogenic Resources Bhd)
Dr. Mohd Hariri Arifin (UKM)
Mr. Nicholas Jacob (JMG)
Ms. Norazianti Asmari (GDS Sdn Bhd)

Councillors 2019-2021:

Prof. Joy Jacqueline Pereira (SEADPRI-UKM)
Dr. Nur Iskandar Taib (UM)
Mr. Tan Boon Kong (Consultant)
Dato' Yunus Abdul Razak (SEADPRI-UKM)

Council Meetings

During the 2019/2020 session, the Council met 6 times. The attendance of the council members to the meetings is presented in the table below. Five meetings were conducted at the meeting room of the Department of Geology, University of Malaya, Kuala Lumpur, and one meeting was carried out via online Zoom Meeting.

Attendance of Council Members at Council Meetings:

NAME	1	2	3	4	5	6	Total
Abdul Rasid Jaapar, Mr	/	/	/	/	0	/	5/6
Ahmad Nizam Hasan, Mr	/	0	/	/	/	/	5/6
Ahmad Tariq Ahmad Ziyad, Mr	/	/	/	/	0	0	4/6
Askury Abd Kadir, Mr	/	/	/	/	/	/	6/6
Farah Fazulah Abdullah, Ms	0	/	0	/	0	/	3/6
Joy Jacqueline Pereira, Prof. Dr	/	/	/	/	/	/	6/6
Lim Choun Sian, Dr	/	/	/	/	/	/	6/6
Mazlan Madon, Dr	/	0	/	0	0	/	3/6
Mohd Hariri Arifin, Dr	/	/	/	/	/	/	6/6
Nicholas Jacob, Mr	0	/	/	0	/	/	4/6
Norazianti Asmari, Ms	/	0	/	/	/	/	5/6
Nur Iskandar Taib, Dr	/	/	/	/	0	/	5/6
Tan Boon Kong, Mr	/	0	/	/	/	0	4/6
Wan Hasiah Abdullah, Prof	/	/	/	/	/	/	6/6
Yunus Abdul Razak, Dato'	0	/	0	0	0	/	2/6

Working Groups

The Working Groups and the Chairs for the session are as follows:

WORKING GROUP (WG)	CHAIRMAN
Engineering Geology & Environmental Geology	Mr. Tan Boon Kong
Promotion of Geoscience & Young Geologists (including Social Media)	Ms. Farah Fazulah Abdullah & Ms. Norazianti Asmari
Economic Geology	Dr. Cheang Kok Keong
Regional Geology	Dr. Mohd Rozi Umor
Geophysics	Dr. Mohd Hariri Arifin
Stratigraphy, Sedimentology & Petroleum Geology	Dr. Meor Hakif Amir Hassan
International Collaboration	Secretary
Quaternary Geology	Mr. Abdullah Sulaiman
Hydrogeology	Mr Abdul Rasid Jaapar

Regional Representatives

The Society is trying to strengthen its delivery mechanism at the sub-national level through the appointment of Regional Representatives to work in conjunction with the local membership to advance geoscience in the respective regions. The Regional Representatives for the session are as follows:

REGIONAL REPRESENTATIVES (RR)	REPRESENTATIVE
Northern Peninsular Malaysia	Dr. Kamar Shah Ariffin
Southern Peninsular Malaysia	Dr. Mohamad Faizal Tajul Baharuddin (UTHM)
Central Peninsular Malaysia	Mr Askury Abd Kadir (UTP)
Eastern Peninsular Malaysia	Dr. Mohammad Muqtada Ali Khan (UMK)
Sarawak	Dr. Dana Badang (JMG)
Sabah	Dr. Rodeano Roslee (UMS)

Membership

As at 31st December 2019, the total number of members in the Society stands at 762, has increased from 689 as of 2018. The increase is mainly from Student category and slight drop decrease in Full Member category. The table below presents the breakdown in membership categories and their geographical breakdown.

Breakdowns of Membership:

COUNTRY	Hon.	Life	Full	Assoc.	Student	Inst.	Total 2019	Total 2018	Total 2017
Malaysia	12 (12)	383 (363)	122 (91)	9 (8)	145 (136)	0	671	610	561
Australia	1 (0)	20 (19)	-	1 (1)	-	-	22	20	20
Bangladesh	-	2 (1)	-	-	-	-	2	1	2
Brunei	-	2 (1)	-	-	-	-	2	1	1
Canada	-	2 (2)	-	-	-	-	2	2	1
China	-	1 (1)	-	-	-	-	1	1	3
Europe	-	12 (11)	0(1)	-	-	3 (2)	15	14	13
Hong Kong	-	1 (2)	-	-	-	-	1	2	2
India	-	1 (1)	-	-	-	-	1	1	1
Indonesia	-	8 (5)	-	-	2 (1)	-	10	6	3
Japan	-	3 (3)	-	-	-	-	3	3	2
Libya	-	3 (3)	-	-	-	-	3	3	2
New Zealand	-	2 (0)	-	-	-	-	2	-	-
Nigeria	-	-	-	-	1 (1)	-	1	-	-
Pakistan	-	1 (0)	-	-	0 (1)	-	1	1	-
Philippines	-	2 (2)	-	-	-	-	2	2	2
Singapore	-	9 (8)	-	(0)	-	0 (1)	9	9	8
Thailand	-	2 (3)	-	-	-	-	2	3	3
USA	-	11 (10)	-	-	1 (0)	-	12	10	7
TOTAL 2019	13	465	122	10	149	3	762	-	-
TOTAL 2018	12	435	92	9	138	3	-	689	-
TOTAL 2017	12	414	102	4	100	2			634

Note: 1. X(Y) --- X=Number for year 2019, Y=Number for year 2019
2. Country – Based on Mailing Address, not Nationality-based

Project, Agreement, Secretariat and Activity

Research Project:

Current project, GSM is one of the partner in the Research Project namely, Disaster Resilient Cities: Forecasting Local Level Climate Extremes and Physical Hazards for Kuala Lumpur, led by SEADPRI-UKM in conjunction with associated Partners in UK and Malaysia in securing the grant Newton-Ungku Omar Fund. GSM's role is to benchmark the process and guide knowledge transfer in the research.

New Project:

A new project, "Promotion of Social Entrepreneurship in Disaster Risk Reduction to Build Community Resilience" commenced on 1 September 2019, funded by the International Development Research Centre (IDRC) for a duration of 3 years. The general objective of the Project is to foster long-term community climate resilience in Malaysia and Cambodia by empowering young social entrepreneurs to develop their own disaster resilience plans. Led by Universiti Kebangsaan Malaysia's SEADPRI-UKM, key partners include the GSM, Royal University of Phnom Pehn (RUPP), and Malaysian DRR Service Organization (MDRRSO).

Agreements:

Two MoUs were inked in this Council Year, with University of Malaya and Universiti Malaysia Kelantan. With UKM, we are in the process of signing. We are also in discussion with UMS for an MoU.

Joint Secretariat:

This Council year, the GSM-IGM Joint Committee met on 31 July 2019 and 15 May 2020. The Joint Committee, an initiative under an agreement signed between GSM and IGM on 5 April 2013 and was tasked to set up various subcommittees with the objectives, among others, to promote education, research, and graduate membership, and to oversee and review geoscience curricula in Malaysian universities. The meetings discussed on future joint organisation of NGC, technical talks, geoscience curricula and continuous professional development programme.

Activities:

The Society has successfully organised its National Geoscience Conference & Exhibition 2019 (NGC2019) with the theme 'Geosciences for the Earth Sustainability' with the collaboration of Universiti Malaysia Sabah (UMS) and Jabatan Mineral dan Geosains Sabah in October 2019 in Kota Kinabalu, Sabah. The NGC 2019 also hold a pre-conference Workshop on the Importance of Geosciences for Sustainable Development and a post conference fieldtrip.

However, for the year 2020, we are inevitably forced to miss the NGC 2020 due to COVID-19 pandemic restriction.

During the session, the Council with the cooperation of Working Groups, Regional Representatives, and in collaboration with UKM, UM, USM, UMS, UMP, IGM, AAPG, JMG, SEGRM, MCoM, BoG and Newton-Ungku Omar project partners were able to organise a total of 31 sessions inclusive of technical talks, workshops, conferences, filed trips and short courses.

Summary of Activities

No	Date	Activity	Topic	Venue	Collaborators
1	27-28 April 2019	Fieldtrip	GSM Sg. Lembing Geo-Mining Tour	Sg Lembing Mines/ Museum	JMG
2	22-26 April 2019	Conference	EAGE-GSM Second Asia Pacific Meeting on Near Surface Geoscience and Engineering	UTM KL	EAGE & UTM
3	17 April 2019	Technical Talk	Uncharted Path of a Malaysian Hydrogeologist | Datuk Ir. Dr. Azuhan bin Mohamed	UKM	IGM, UKM
4	16 April 2019	Forum	GSM-IGM Flagship on Geoscience to Action for Disaster Risk Reduction: Disaster Risks, Business Continuity Management and Insurance: An Emerging Market for Geoscientists?	UM	UKM, IGM, UM
5	2-3 July 2019	Conference	National Groundwater Conference 2019	Shah Alam	IGM, JMG, BoG
6	1 Aug 2019	Seminar	Advanced Seminar on Economic Geology & Mineral Resources	UM	GSM, JMG, IGM, UM, UMP, USM, MCoM
7	21 – 23 Aug 2019	Short Course	International Short Course Series: Rock Slope Engineering	UM	SEGRM, UM
8	18 Sept 2019	Technical Talk	Peranan Agensi Angkasa Malaysia (MYSA) Dalam Pembangunan Teknologi Angkasa di Malaysia | Tuan Hj. Azlikamil Napiah,	UKM	UKM, IGM
9	19 Sept 2019	Workshop	National Marine Geology Workshop	UM	UM, UTP, JMG, IGM, UMK
10	23 – 24 Sept 2019	Conference & Exhibition	UTP: Asia Geoscience Student Conference & Exhibition (AGSCE)	UTP	UTP
11	25 – 27 Sept 2019	Conference	Regional Geoheritage Conference 2019	Sarawak	UKM, JMG
12	1 – 3 Oct 2019	Conference	National Geoscience Conference 2019	Sabah	UMS, JMG

13	3 – 5 Oct 2019	Seminar	Seminar Bencana Alam	Sabah	UMS
14	9 Oct 2019	Technical Talk	Industri Kuari di Malaysia | En. Amirruddin Rosni	UKM	UKM, IGM
15	14-16 Oct 2019	Forum	Geoscience for Enhancing Disaster Resilience in Kuala Lumpur Workshop on Building Disaster and Climate Resilience in Cities	UM & KL	SEADPRI-UKM, ANCST, IGM
16	16 Oct 2019	Technical Talk	The Quranic Perspective on Geology | Mr. Zaim Zamri	UKMN	UKM, IGM
17	21 Oct 2019	Technical Talk	Young Geologist: Challenges and Opportunities/ Let the Rocks Talk | Dr. Kamaludin Hassan, En. Abd Rashid Jaapar, En. Wan Saifulbahari Wan Mohammad, En. Abdullah Sulaiman	UMT	UMT, JMG
18	23 Oct 2019	Technical Talk	Teledyne Optech Polaris Terrestrial Laser Scanner: A case study in Kundasang, Sabah | Jespal Singh Gill	UKM	UKM, IGM
19	24 Oct 2019	Workshop	GSM-IGM Focus Group Discussion on Current Issues and Challenges with Geoscience Consultancy and Services	PAUM, UM	IGM
20	26 Oct 2019	Fieldtrip	Geological Fieldwork & Geologist Night 2019	Sarawak	IGM, BOG, JMG
21	26 Oct 2019	Workshop	Workshop on IPCC Role, Activities and Findings	Academy of Sciences Malaysia	SEADPRI-UKM, ANCST, IGM, ASM
22	6 Nov 2019	Technical Talk	Geosains Dan Industri Revolusi (IR) 4 | Prof. Madya Dr Rohayu Che Omar	UKM	UKM, IGM
23	16 Nov 2019	Fieldtrip	Hotspring Hunting 2019 Ulu Slim-Sungkai, Perak | Dr. Mohd Hariri Arifin	Perak	UKM, IGM
24	27 Nov 2019	Technical Talk	Tanah runtuh pendam-lama – Daripada geobahaya kepada geobencana (Old-dormant landslides – from geohazards to geodisasters) | Assoc. Dr. Tajul Anuar Jamaluddin	UKM	UKM, IGM
25	4 Dec 2019	Technical Talk	1) The Hidden Treasure of Sarawak Petrified Wood: Silicification Mechanism | Tuan Hj. Askury Abd. Kadir 2) Micro-to-meso scale heterogeneities: Implications on Petroleum Reservoir Quality | Ekundayo Joseph Adepehin	UKM	UKM, IGM
26	21 Jan 2020	Workshop	The Workshop on Promotion of Social Entrepreneurship in Disaster Risk Reduction	Concorde Hotel Shah Alam	SEADPRI-UKM, ANCST, IGM, ASM
27	19 Feb 2020	Technical Talk	Sambung Belajar di Dalam atau Luar Negara? Pengalaman dan Perkongsian |Nor Shahidah Mohd Nazer, Norasiah Sulaiman, Mohd Hariri Arifin dan Muhammad Ashahadi Dzulkafli	UKM	UKM, IGM
28	4 Mar 2020	Technical Talk	1) Studying in the US: A Malaysian Geologist's Experience | Lisa NurMarini binti Mohd Kamal 2) Cabaran Kebolehpasaran Geologis dalam Industri – Survival for the Fittest | Ahmad Nizam Hasan	UKM	UKM, IGM
29	11 Mar 2020	Technical Talk	Bidang Tugas Ahli Petrofizik dalam Evaluasi Batu Takungan | Fadzlin Hasani Bin Kasim	UKM	UKM, IGM
30	20 May 2020	Technical Talk	Perlombongan Pasir di Laut | Mr Abdulah Sulaiman	Zoom Platform	IGM, JMG
31	4 June 2020	Forum	Bicara 50 Tahun Geologi UKM (1970-2020)	Zoom Platform	UKM, IGM

GSM Awards

GSM has set up numerous awards for members, namely Honorary Membership, Hutchison Best Student Award, N.S. Haile Publication Award, and DJ Gobbett Award. A few nominations for awards were made and planned to be presented at NGC2020, but were put on hold due to postponement of NGC2020.

Linkages and Collaborations

GSM maintained linkages with national and international institutions such as:

- Institute of Geology Malaysia
- Confederation of Scientific and Technological Association of Malaysia (COSTAM)
- Formation Evaluation Society Malaysia (FESM)
- American Association of Petroleum Geology (AAPG)
- Newton Ungku Omar Fund and IGM-GSM Flagship since July 2015
- GEOSEA
- MoU with NrgEdge, University of Malaya, Universiti Malaysia Kelantan
- Asian Network on Climate Science and Technology, and Newton-Ungku Omar project partners
- Society of Exploration Geophysicists (SEG)
- For the Student's Geological Club Collaboration; AAPG Student Chapter of University of Malaya, UMK, UMS etc.

Acknowledgement

The Society would like to record its utmost appreciation to all the individuals and organisations in organising the Society's numerous activities during the session. Special mention must be made of the tremendous support by the Head and staff of the Geology Department, University of Malaya especially in the use of its premises for most of the Society's meetings and activities. The continued co-operation and support extended by JMG, PETRONAS, UKM, UMS, UTP, IGM, ANCST and Newton-Ungku Omar project partners is recorded with gratitude. The unwavering support of Ms. Anna Lee and Ms Wan Aida in the administration of GSM is also very much appreciated. Last but not least, the Council also wishes to record its appreciation to all GSM members for their advice, guidance and support throughout the session.

LIM CHOUN SIAN
Secretary 2019/2020
Geological Society of Malaysia

ASSISTANT SECRETARY'S REPORT

The sales of the Society publications and the list of organizations and institutions that were exchanging publications with GSM are presented in the following tables.

Sales and stock of publications for 2019 (Bulletin only)

Publications	Sales 2019	Stock remaining by end of 2019	Remarks
Bulletin 1	Out of Stock		
Bulletin 2	0	164	
Bulletin 3	10	126	
Bulletin 4	10	40	
Bulletin 5	Out of Stock		
Bulletin 6	10	361	
Bulletin 7	10	220	
Bulletin 8	Out of Stock		
Bulletin 9	Out of Stock		
Bulletin 10	Out of Stock		
Bulletin 11	Out of Stock		
Bulletin 12	Out of Stock		
Bulletin 13	Out of Stock		
Bulletin 14	Out of Stock		
Bulletin 15	Out of Stock		
Bulletin 16	Out of Stock		
Bulletin 17	Out of Stock		
Bulletin 18	Out of Stock		
Bulletin 19	10	341	
Bulletin 20	10	294	
Bulletin 21	10	93	
Bulletin 22	10	170	
Bulletin 23	10	183	
Bulletin 24	10	342	
Bulletin 25	10	50	
Bulletin 26	10	150	
Bulletin 27	10	24	
Bulletin 28	10	59	
Bulletin 29	10	74	
Bulletin 30	0	100	

Publications	Sales 2019	Stock remaining by end of 2019	Remarks
Bulletin 31	10	76	
Bulletin 32	10	50	
Bulletin 33	10	208	
Bulletin 34	10	29	
Bulletin 35	Out of Stock		
Bulletin 36	10	62	
Bulletin 37	10	114	
Bulletin 38	10	180	
Bulletin 39	Out of Stock		
Bulletin 40	10	64	
Bulletin 41	Out of Stock		
Bulletin 42	10	Out of Stock	
Bulletin 43	10	96	
Bulletin 44	10	14	
Bulletin 45	Out of Stock		
Bulletin 46	Out of Stock		
Bulletin 47	Out of Stock		
Bulletin 48	10	6	
Bulletin 49	10	268	
Bulletin 50	10	305	
Bulletin 51	10	178	
Bulletin 52	10	192	
Bulletin 53	10	290	
Bulletin 54	10	240	
Bulletin 55	10	264	
Bulletin 56	10	312	
Bulletin 57	10	23	
Bulletin 58	10	Out of Stock	
Bulletin 59	10	77	
Bulletin 60	10	78	
Bulletin 61	10	38	
Bulletin 62	10	51	
Bulletin 63	10	51	
Bulletin 64	10	51	
Bulletin 65	10	*688	* Includes free copies to members; AGC – Annual Geological Conference
Bulletin 66	10	*689	
E-Bulletin 67	**14	36	** For Ministry of Internal Affairs, the National Library and standing orders subscribers
E-Bulletin 68	**14	36	

Sales and stock of publications for 2019 (All other GSM publication)

Other Publications	Sales 2019	Stock remaining by end of 2019
Proceeding AGC 2000	Out of Stock	
Proceeding AGC 2001	5	102
Malaysian Stratigraphic guide	Out of Stock	
Lexicon of stratigraphy	Out of Stock	
Stratigraphic correlation	Out of Stock	
Rocks poster	Out of Stock	
Geology of Borneo (CD)	Out of Stock	
Geology of Borneo (Map)	5	677
Geol. Evolution of SEA	47	374
Geology of P. Malaysia	75	384

There was a consensus decision made to digitize the Bulletin as of 2019 within the Council Members, hence as of E-Bulletin 67 onwards, only 50 hard printed copies with limited distribution to standing orders subscribers. Prior to this year 750 copies were printed for each bulletins, subject to total membership total.

Remaining stock of 2019 is calculated based on 51st AGM report listing with subtraction on subsequent AGM numbers. Moving forward, it is recommended that publication stock report should include both remaining stock and number of sales to date.

List of organizations and institutions that are exchanging publications with GSM

Item	Organization	Country
1	New South Wales Dept of Mineral Resources	Australia
2	Geologica Belgica a.s.b.I	Belgium
3	University of Geosciences	China
4	Nanking Institute of Geology	China
5	National Geological Library	China
6	Peking College of Geology	China
7	Suomalaineu Tiedeakatemia	Finland
8	Freie Universitat Berlin	Germany
9	National Museum of Natural History	Holland
10	Geological Society of Japan	Japan
11	Dept Mineral & Planetary Science, Hiroshima	Japan
12	Museum of Nature & Human Activities	Japan
13	National Science Museum	Japan
14	Natural History Museum and Institute	Japan
15	Institute of Geosciences	Japan
16	Geological Society of Korea	Korea
17	Dewan Bahasa dan Pustaka	Malaysia
18	Minerals and Geoscience Department Malaysia, Headquarters	Malaysia
19	Minerals and Geoscience Department Malaysia, Ipoh	Malaysia
20	Minerals and Geoscience Department Malaysia, Kuching	Malaysia
21	Minerals and Geoscience Department Malaysia, Kota Kinabalu	Malaysia

22	Kementerian Dalam Negeri	Malaysia
23	Perpustakaan Negara Malaysia	Malaysia
24	Library PETRONAS Berhad	Malaysia
25	Pusat Sumber Maklumat Negeri Sarawak	Malaysia
26	Perpustakaan Tun Sri Lanang, UKM	Malaysia
27	Program Geologi, UKM	Malaysia
28	Library, UM	Malaysia
29	Library, USM	Malaysia
30	Malaysian Institute of Nuclear Technology	Malaysia
31	Library of Congress, USA Embassy	Malaysia
32	Institute of Ecological & Nuclear Science	New Zealand
33	National Library	Singapore
34	Central Geological Survey	Taiwan
35	American Museum of Natural History, New York	USA
36	CIGESE Library	USA
37	Oklahoma Geological Survey	USA
38	US Geological Survey	USA
39	University of Kansas	USA
40	AAPG Foundation Library	USA
41	Senckenberg Research Institute and Natural History Museum Frankfurt	Germany

FARAH FAZULAH ABDULLAH
Assistant Secretary 2019/2020
Geological Society of Malaysia

EDITOR'S REPORT

In 2019, four issues of Warta Geologi (Volume 45) and two volumes of the GSM Bulletin (Volume 67 and 68) were published, and thus the status of publication is currently up to date. The Society is grateful to authors for their contributions, reviewers and members of the Editorial Board for their time and effort to improve the quality of the Society's publications. The reviewers for the 2019 Bulletin and Warta issues are as listed on page 27 in Warta Geologi volume 46 (1).

The GSM online publication website is now in its 7th year. In 2019, the website was viewed by more than 48,000 visitors (with an average of 4,029 visitors/month) from more than 120 countries (mainly Malaysia, United States, Singapore, Germany, Poland, China, Indonesia, Thailand and Russia), with 21,023 (1,751/month) views/downloads.

All issues of the Bulletin are now available from the MyJurnal website. Beginning this year (2020) all Geological Notes and Other Notes from the Warta Geologi will also be made available at the MyJurnal site.

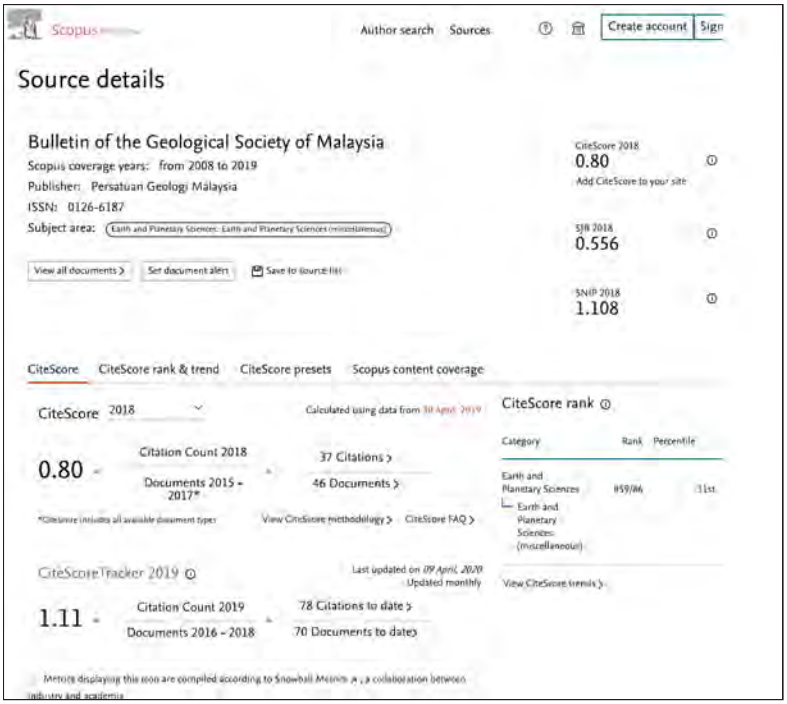
The Bulletin of the Geological Society of Malaysia received the Jurnal Crème 2019 acknowledgement in November 2019, for SCOPUS category journals in the field of Science, Technology and Medical. The acknowledgement was awarded by the Ministry of Education Malaysia in collaboration with Clarivate Analytics and Elsevier.

WoS indexing

The application for indexing of the Bulletin in the Web of Science was not successful. The Editorial Committee will submit the volume 71 Bulletin of 2021 for revaluation.

Citation of the Bulletin

Total CiteScore and recent citation (2015-2019; updated by Scopus on 9/04/2020) is as shown below:



May I take this opportunity to thank all the editorial committee members for their assistance during the editorial process.

WAN HASIAH ABDULLAH
Editor 2019/2020
Geological Society of Malaysia

TREASURER'S REPORT

For the Financial Year 2019, the society's posted a surplus of RM 42,588.00 compared to year 2018 with a deficit of RM 48,054.00.

Operating revenue for year 2019 posted an increase with a total income of RM 161,972.00 compared to year 2018 of RM 73,786.00.

The revenue posted for Subscription shows lower from RM 19,142.00 of year 2018 to RM 18,194.00 for year 2019, income for National Geoscience Conference (NGC 2019) which is co-organize with Universiti Malaysia Sabah (UMS) and held in Kota Kinabalu, Sabah shown deficit of RM 6,008.00 compare to surplus of RM 4,082.00 in NGC 2018.

Sales of publications are RM 34,781.00 higher compare to RM 28,250.00 for year 2018. Accordingly, there has been a decline in interest rates from fixed deposits from RM 19,142.00 for year 2018 to RM 18,194.00 for year 2019.

Income for Geology of Peninsular Malaysia shows higher for year 2019 with an increase of RM 9,650.00 compare to year 2018 of RM 4,920.00 and SEGRM-GSM forum higher for year 2019 of RM 14,373.00 compare year 2018 of RM 636.00. Finally, higher sales of Geological Evolution of Southeast Asia publication in year 2019 with RM 3,580 compare to RM 1,090.00 for year 2018.

Total operating expenditure for Financial Year 2019 shows slightly lower from RM 121,705.00 for year 2018 to RM 119,112.00.

Expenses of Annual Dinner 2019 show slightly higher from RM 2,086.00 for year 2018 to RM 2,326.00. Nevertheless, Honorarium shows lower from RM 25,650.00 for year 2018 to RM 24,750.00 for year 2019. There was an increment of audit fee for year 2019 of RM 1,590.00 compare to year 2018 of RM 1,272.00 and contractual fixed rental amount of GSM administrative office at Department of Geology, Universiti Malaya for year 2019 of RM 12,000.00 compare to year 2018 of RM 8,665.00.

The National Geoscience Conference year 2019 shows deficit of RM 6,008 compare to slightly surplus year 2018 of RM 3,524.00. Printing of Warta Geologi are RM 19,625.00 lower compare to RM 19,734.00 for year 2018 and Bulletin also shows lower from RM 25,650.00 for year 2018 to RM 22,800.00 for year 2019.

Expenses on speaker`s account shows lower for year 2019 of RM 729.00 compare to RM 1,936.00 for year 2018. Total expenditure Information Technology (Webmaster) also shows lower for year 2019 of RM 5,718.00 compare year 2018 of RM 11,129.00.

While an increase for Sponsorship for student's activities for year 2019 from RM 5,730.00 for year 2018 to RM 9,521.00 but slightly lower for student's award from RM2,000.00 for year 2018 to RM1,000.00 for year 2019 and souvenirs of RM 1,526.00 compare to year 2018 of RM4,570.00. Finally, there was an expenditure incurred in organizing the IGM-GSM Workshop, Working Group activities and Sg Lembing Field trip for year 2019 with total amount of RM 2,663.00.

For year 2019 there was an increase in Endowment fund with a total amount of RM 1,737,653.00 compare to RM 1,729,239.00 for year 2018, held as fixed deposit (FD) in UOB Bank given an accrued interest of RM58,414.00 held in UOB Bank current account.

Finally, the net current asset showed an increase by RM 38,548.00 from RM 2,640,152.00 for year 2018 to RM 2,677.079.00 for year 2019. While Property, Plant and Equipment of our non-current assets depreciate from total value of year 2018 RM 1,855.00 to RM 1,622.00 for year 2019.

The Hon.Treasure would like to express a great appreciation to rest of the donors and sponsors on their contributions and supports throughout the year. Last but not least to Ms Anna Lee on her contribution managing the accounts throughout the year.

AHMAD NIZAM HASAN
Treasurer 2018/2019
Geological Society of Malaysia

NOTES

1. The RM 11,276 are AAPG-UM student chapter fund held into our current account to finance their activities.
2. Young geoscientist award fund of RM 3,143.00 still held as no candidates nominated.
3. The fixed deposits with licensed bank have a maturity of between 6 to 15 months (2018: 6 to 15 months). Interest rates for the deposits ranged from (2018: 2.85% to 2.95%) per annum.

HONORARY AUDITOR'S REPORT

PERSATUAN GEOLOGI MALAYSIA
(GEOLOGICAL SOCIETY OF MALAYSIA)
(Registered in Malaysia)

FINANCIAL STATEMENTS
31 DECEMBER 2019

PERSATUAN GEOLOGI MALAYSIA
(GEOLOGICAL SOCIETY OF MALAYSIA)
(Registered in Malaysia)

THE COUNCIL MEMBERS INFORMATION FOR 2019 / 2020

President	:	Mr. Abd Rasid Jaapar (Geomapping Technology)
Vice President	:	Mr. Askury Abd Kadir (UTP)
Immediate Past President	:	Dr. Mazlan Madon (Petronas)
Secretary	:	Dr. Lim Choun Sian (UKM)
Assistant Secretary	:	Farah Fazullah Abdullah (Carigali Hess Operating Company)
Treasurer	:	Mr. Ahmad Nizam Hasan (GeoSolution Resources)
Editor	:	Prof Dr Wan Hasiah Abdullah (UM)
Councillors (1 Year) (2017/2019)	:	Mr. Tan Boon Kong (Consultant)
	:	Dr. Nur Iskandar Taib (UM)
	:	Nicholas Jacob (JKR)
	:	Dato' Yunus Abdul Razak
	:	(SEADPRI-UKM)
Councillors (2 Years)	:	Mr. Ahmad Tariq Ahmad Ziyad
	:	(Orogenic Resources Bhd)
	:	Mohd Hariri Arifin (UKM)
	:	Joy Jacqueline Pereira (SEADPRI-UKM)
	:	Norazianti Asman (GDS Sdn Bhd)

PERSATUAN GEOLOGI MALAYSIA
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(Registered in Malaysia)

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PERSATUAN GEOLOGI MALAYSIA
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COUNCIL'S REPORT

The Council hereby present their report together with audited financial statements of the Society for the financial year ended 31 December, 2019.

PRINCIPAL OF ACTIVITY

The principal activity of the Society is to promote the advancement of the geological sciences in Malaysia. There has been no significant changes in the nature of this activity during the year.

RESULT

Net surplus for the year	RM42,588

There were no material transfer to or from reseves or provisions during the financial year.

In the opinion of the Council, the results of the operations of the Society during the year were not substantially affected by any item, transaction or event of a material and unusual nature.

COUNCIL MEMBERS

The names of the Council Members of Persatuan Geologi Malaysia in office since the date of the last report are:-

Abd Rasid Jaapar
Ahmad Nizam Hasan
Ahmad Tariq Ahmad Ziyad
Askury Abd Kadir
Farah Fazullah Abdullah
Joy Jacqueline Pereira
Lim Choun Sian
Mazlan Madon
Mohd Hariri Arifin
Nicholas Jacob
Norazianti Asmari
Nur Iskandar Taib
Tan Boon Kong
Wan Hasiah Abdullah
Yunus Abdul Razak

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COUNCIL'S BENEFITS

Neither at the end of the financial year, nor at any time during that year, did there subsist any arrangement to which the Society was a party, whereby the Council Members might acquire benefits by means of the acquisition of interest in the Society or any other body corporate.

Since the end of the previous financial year, no Council Member has received or become entitled to receive a benefit by reason of a contract made by the Society or a related corporation with any Council Member or with a firm which he is a member, or with a Company in which he has a substantial financial interest.

COUNCIL'S INTEREST

None of the Council Members in office since at the end of the financial year had any interest in the Council or its related corporations during the financial year.

COUNCIL'S REMUNERATION

None of the Council Members in office since at the end of the financial year had received any remunerations from the Society or its related corporations during the year.

OTHER STATUTORY INFORMATION

(I) AS AT THE END OF THE FINANCIAL YEAR

(a) Before the financial statements were made out, the Council Members took reasonable steps:-

- (i) to ascertain that proper action had been taken in relation to the writing off of bad debts and satisfied themselves that there were no known bad debts and that no provision for doubtful debts was necessary; and

- (ii) to ensure that any current assets which were unlikely to realise their values as shown in the accounting records in the ordinary course of business had been written down to an amount which they might be expected so to realise.

(b) At the date of this report, the Council are not aware of any circumstances not otherwise dealt with in this report or the financial statements of the Society which would render:

- (i) it necessary to write off any bad debts or to make any provision for doubtful debts in respect of the financial statements of the society; and

- (ii) the values attributed to current assets in the financial statements of the Society misleading.

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(c) As the date of this report, the Council Members are not aware of any circumstances which have arisen which would render adherence to the exiting method of valuation of assets or liabilities of the Society misleading or inappropriate.

(d) As the date of this report, the Council Members are not aware of any circumstances not otherwise dealt with in this report or to the financial statements of the Society which would render any amount stated in the financial statements misleading.

(e) As at the date of this report, there does not exist:

  (i) any charge on the assets of the Society which as arisen since the end of the financial year which secures the liabilities of any other person; or

  (ii) any contingent liability in respect of the Society which has arisen since the end of the financial year.

(f) In the opinion of the Council Members:

  (i) no contingent liability or other liability has become enforceable, or is likely to become enforceable, within the period of twelve months after the end of the financial year which will or may affect the ability of the Society to meet its obligations as and when they fall due; and

  (ii) no item, transaction or event of a material and usual nature has arisen in the internal between the end of the financial year and the date of this report which is likely to affect substantially the results of the Society for the financial year in which this report is made.

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AUDITORS' AND AUDITORS' REMUNERATION

The auditors Messrs S.F. Lee & Co. have expressed their willingness to continue in office,

Auditors' remuneration of the Society for the financial year ended 31 December 2019 is RM1,500/-

Signed on behalf of the Council in accordance with a resolution of the Council dated
10 MAR 2020

Abd Rasid Jaapar
President

Ahmad Nizam Hasan
Treasurer

Kuala Lumpur, Malaysia

PERSATUAN GEOLOGI MALAYSIA
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STATEMENT BY COUNCIL PURSUANT TO SECTION 251(2) OF THE COMPANIES ACT, 2016

We, Abd Rasid Jaapar and Ahmad Nizam Hasan, being two of the Council Members of Persatuan Geologi Malaysia (Geological Society Of Malaysia), do hereby state that, in our opinion, the accompanying financial statements set out pages 9 to 20 are drawn up in accordance with Malaysian Private Entities Reporting Standard and the requirements of the Companies Act, 2016 in Malaysia so as to give a true and fair view of the financial position of the Persatuan Geologi Malaysia (Geological Society Of Malaysia), as at 31 December 2019, and of the financial performance and cash flows of the Society for the year then ended.

Signed on behalf of the Board in accordance with a resolution of the Council dated
10 MAR 2020

Abd Rasid Jaapar
President

Ahmad Nizam Hasan
Treasurer

Kuala Lumpur

STATUTORY DECLARATION PURSUANT TO SECTION 251(1)(b) OF THE COMPANIES ACT, 2016

I, Ahmad Nizam Hasan, being the officer primarily responsible for the financial management of Persatuan Geologi Malaysia (Geological Society Of Malaysia), do solemnly and sincerely declare that the accompanying financial statements set out on pages 9 to 20 are in my opinion correct, and I make this solemn declaration conscientiously believing the same to be by virtue of the provisions of the Statutory Declarations Act, 1960.

Subscribed and solemnly declared by abovenamed
Ahmad Nizam Hasan at Kuala Lumpur in Wilayah
Persekutuan on 10 MAR 2020

Ahmad Nizam Hasan

Before me:

Kuala Lumpur

PESURUHJAYA SUMPAH
W 678
KAPT (B) AFFANDI
BIN AHMAD
1 JAN 2019 - 31 DIS 2021
MALAYSIA

No. 86, Jalan Putra
50350 Kuala Lumpur

5

S.F. LEE & CO (AF: 0670)
CHARTERED ACCOUNTANTS

**INDEPENDENT AUDITORS' REPORT
TO THE MEMBERS OF PERSATUAN GEOLOGI MALAYSIA (GEOLOGICAL SOCIETY OF MALAYSIA)**

Report on the Financial Statements

Opinion

We have audited the financial statements of **Persatuan Geologi Malaysia (Geological Society Of Malaysia)**, which comprise the statement of financial position of the Society as at 31 December 2019, the statement of income and expenditure and statement of cash flows of the Society for the year then ended, and a summary of significant accounting policies and other explanatory notes, as set out on pages 9 to 20.

In our opinion, the accompanying financial statements give a true and fair view of the financial position of the Society as at 31 December 2019, and of its financial performance and its cash flows for the year then ended in accordance with Malaysian Private Entities Reporting Standard and the requirements of the Companies Act, 2016 in Malaysia.

Basis for opinion

We conducted our audit in accordance with approved standards on auditing in Malaysia and International Standards on Auditing. Our responsibilities under those standards are further described in the Auditor's Responsibilities for the Audit of the Financial Statements section of our report. We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our opinion.

Independence and Other Ethical Responsibilities

We are independent of the Society in accordance with the By-Laws (on Professional Ethics, Conduct and Practice) of the Malaysian Institute of Accountants ("By-Laws') and the International Ethics Standards Board for Accountants' Code of Ethics for Professional Accountants ("IESBA Code"), and we have fulfilled our other ethical responsibilities in accordance with the By-Laws and the IESBA Code.

Information Other than the Financial Statements and Auditors' Report Thereon

The council members of the Society are responsible for the other information. The other information comprises the Council's Report but does not include the financial statements of the Society and our auditors' report thereon.

Our opinion on the financial statements of the Society does not cover the Council's Report and we do not express any form of assurance conclusion thereon.

In connection with our audit of the financial statements of the Society, our responsibility is to read the Council's Report and, in doing so, consider whether the Council's Report is materially inconsistent with the financial statements of the Society or our knowledge obtained in the audit or otherwise appears to be materially misstated.

If, based on the work we have performed, we conclude that there is a material misstatement of the Council's Report, we are required to report that fact. We have nothing to report in this regard.

Branch add : G - 23A, Jalan SP 5/5, Seksyen 5,
Taman Serdang Perdana, 43300 Seri Kembangan,
Selangor Darul Ehsan.
Tel : 603-8938 1870 Fax : 603-8943 4901

APPROVED EMPLOYER ACCA SILVER

S.F. LEE & CO (AF: 0670)

PERSATUAN GEOLOGI MALAYSIA
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Responsibilities of the Council for the Financial Statements

The Council of the Society are responsible for the preparation of financial statements of the Society that give a true and fair view in accordance with Malaysian Private Entities Reporting Standard and the requirements of the Companies Act, 2016 in Malaysia. The Council are also responsible for such internal control as council determine is necessary to enable the preparation of financial statements of the Society that are free from material misstatement, whether due to fraud or error.

In preparing the financial statements of the Society, the council are responsible for assessing the Society's ability to continue as a going concern, disclosing, as applicable, matters related to going concern and using the going concern basis of accounting unless the council either intend to liquidate the Society or to cease operations, or have no realistic alternative but to do so.

Auditor's Responsibilities for the Audit of the Financial Statements

Our objectives are to obtain reasonable assurance about whether the financial statements of the Society as a whole are free from material misstatement, whether due to fraud or error, and to issue an auditors' report that includes our opinion. Reasonable assurance is a high level of assurance, but is not a guarantee that an audit conducted in accordance with approved standards on auditing in Malaysia and International Standards on Auditing will always detect a material misstatement when it exists. Misstatements can arise from fraud or error and are considered material if, individually or in the aggregate, they could reasonably be expected to influence the economic decisions of users taken on the basis of these financial statements.

As part of an audit in accordance with approved standards on auditing in Malaysia and International Standards on Auditing, we exercise professional judgment and maintain professional skepticism throughout the audit. We also:

(a) Identify and assess the risks of material misstatement of the financial statements of the Society, whether due to fraud or error, design and perform audit procedures responsive to those risks, and obtain audit evidence that is sufficient and appropriate to provide a basis for our opinion. The risk of not detecting a material misstatement resulting from fraud is higher than for one resulting from error, as fraud may involve collusion, forgery, intentional omissions, misrepresentations, or the override of internal control.

(b) Obtain an understanding of internal control relevant to the audit in order to design audit procedures that are appropriate in the circumstances, but not for the purpose of expressing an opinion on the effectiveness of the Society's internal control.

(c) Evaluate the appropriateness of accounting policies used and the reasonableness of accounting estimates and related disclosures made by the council.

S.F. LEE & CO (AF : 0670)

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(d) Conclude on the appropriateness of the council's use of the going concern basis of accounting and, based on the audit evidence obtained, whether a material uncertainty exists related to events or conditions that may cast significant doubt on the Society's ability to continue as a going concern. If we conclude that a material uncertainty exists, we are required to draw attention in our auditors' report to the related disclosures in the financial statements of the Society or, if such disclosures are inadequate, to modify our opinion. Our conclusions are based on the audit evidence obtained up to the date of our auditors' report. However, future events or conditions may cause the Society to cease to continue as a going concern.

(e) Evaluate the overall presentation, structure and content of the financial statements of the Society, including the disclosures, and whether the financial statements represent the underlying transactions and events in a manner that achieves fair presentation.

We communicate with the council regarding, among other matters, the planned scope and timing of the audit and significant audit findings, including any significant deficiencies in internal control that we identify during our audit.

Other Matter

This report is made solely to the members of the Society, as a body, in accordance with Section 266 of the Companies Act, 2016 in Malaysia and for no other purpose. We do not assume responsibility to any other person for the content of this report.

S.F. LEE & CO.
AF 0670
CHARTERED ACCOUNTANTS

LEE SIEW FATT
01179/09/2020 (J)
CHARTERED ACCOUNTANT

Kuala Lumpur
Dated: 10 MAR 2020

PERSATUAN GEOLOGI MALAYSIA
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STATEMENT OF FINANCIAL POSITION
As at 31 December 2019

	Note	2019 RM	2018 RM
FUND ACCOUNTS			
GENERAL FUND	4	911,525	868,937
ENDOWMENT FUND	5	1,737,653	1,729,239
STUDENT LOAN FUND		1,755	955
YOUNG GEOSCIENTIST AWARD FUND		3,143	3,143
AAPG-UM STUDENT CHAPTER FUND	6	11,276	10,779
DRCKL FUND	7	11,727	27,099
		2,677,079	2,640,152
Represented by:			
NON-CURRENT ASSETS			
PROPERTY, PLANT AND EQUIPMENT	8	12,727	14,348
CURRENT ASSETS			
Deposits		600	600
Fixed deposits with licensed bank	9	2,229,701	2,229,701
Cash and bank balances		481,312	481,714
		2,711,613	2,712,015
CURRENT LIABILITIES			
Other payables		47,129	86,211
Current tax liabilities		132	-
		47,261	86,211
NET CURRENT ASSETS		2,664,352	2,625,804
		2,677,079	2,640,152

The annexed notes form an integral part of the financial statements.

PERSATUAN GEOLOGI MALAYSIA
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STATEMENT OF INCOME AND EXPENDITURE
For the year ended 31 December 2019

INCOME	**Note**	**2019 RM**	**2018 RM**
Tranfer from endowment fund		50,000	-
Advanced seminar on economic geology		12,129	-
Entrance fee		1,400	860
Fixed deposits interest income		18,194	19,142
Subscription		17,585	14,806
Sales of publications		34,781	28,250
Geology of Peninsular Malaysia		9,650	4,920
National Geoscience Conference		-	4,082
SEGRM-GSM forum		14,373	636
Geological Evolution of Southeast Asia		3,580	1,090
Fieldtrip - hotsprings		280	-
		161,972	73,786
EXPENDITURE			
Annual dinner		2,326	2,086
Audit fee		1,590	1,272
Bank charges		128	141
Brain storming session		-	2,123
Depreciation on property, plant and equipment		1,622	1,855
Department of geology		12,000	8,665
Geosea		-	2,428
Honorarium		24,740	24,750
National Geoscience Conference		6,008	558
Postages		1,748	3,889
Printing and Stationery			
- Warta Geologi		19,625	19,734
- Bulletin		22,800	25,650
- Stationery		-	209
Professional fee		800	959
Refreshment		1,061	271
Speakers' account		729	1,936
Sponsorship for student's activities		9,521	5,730
Student's award		1,000	2,000
Souvenirs		1,526	4,570
Miscellaneous expenses		3,507	1,662
Information Teknologi		5,718	11,129
Young geologists network		-	88
Field trip - sungai lembing		33	-
Working group		933	-
IGM - GSM workshop		1,697	-
		119,112	121,705
Surplus / (deficit) before tax		42,860	(47,919)
Income tax expense	10	(272)	(135)
Net surplus / (deficit) for the year		42,588	(48,054)

The accompanying notes are an integral part of the financial statements

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STATEMENT OF CASH FLOWS
For the year ended 31 December 2019

	2019 RM	2018 RM
Cash flows from operating activities		
Surplus / (Deficit) of income over expenditure for the year	42,860	(47,919)
Adjustments for:-		
Depreciation on property, plant & equipment	1,622	1,855
Interest income	(18,194)	(19,142)
Surplus / (Deficit) before working capital changes	26,288	(65,206)
Increase in student loan fund	800	-
Increase in Endowment Fund	8,414	56,719
Increase / (Decrease) in AAPG-UM Student Chapter Fund	497	(109)
(Decrease) / Increase in other payables	(54,454)	25,949
Cash (used in) / generated from operations	(18,455)	17,353
Tax paid	(141)	(135)
Interest income	18,194	19,142
Net cash (used in) / generated from operating activities	(402)	36,360
Net (decrease) / increase in cash and cash equivalents	(402)	36,360
Cash and cash equivalents at beginning of the year	2,711,415	2,675,055
Cash and cash equivalents at end of the year	2,711,013	2,711,415

Cash and cash equivalents comprised of:	2019 RM	2018 RM
Deposits held with licensed banks	2,229,701	2,229,701
Cash and bank balances	481,312	481,714
	2,711,013	2,711,415

The accompanying notes are an integral part of the financial statements

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NOTES TO THE FINANCIAL STATEMENTS –31 DECEMBER 2019

1. CORPORATE INFORMATION

The principal activity of the Society is to promote the advancement of the geological sciences in Malaysia. There has been no significant changes in the nature of this activity during the year.

The Society is registered in Malaysia. The registered office of the Society is located at University Malaya, 59100 Kuala Lumpur.

The financial statements were authorised for issue in accordance with a resolution by the Council on 10 MAR 2020

2. SIGNIFICANT ACCOUNTING PILICIES

(a) Statement of compliance

The financial statements of the Society have been prepared in accordance with Malaysian Private Entities Reporting Standard ("MPERS") and the requirements of Companies Act, 2016 in Malaysia.

(b) Basis of measurement

The financial statements have been prepared on the historical cost basis except as otherwise stated in the financial statements.

(c) Functional and presentation currency

These financial statements are presented in Ringgit Malaysia ("RM"), which is the Society's functional currency.

(d) Significant accounting estimates and judgements

The preparation of the financial statements in conformity with MPERS requires the use of certain accounting estimates and exercise of judgements. Estimates and judgements are continuously evaluated and are based on past experience, reasonable expectations of future events and other factors.

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The Council are the opinion that there are no key assumptions concerning the future and other key sources of estimation uncertainty at the reporting date, that have a significant risk of causing material adjustment to the carrying amounts of assets and liabilities within next financial year.

3. SUMMARY OF ACCOUNTING POLICIES

(a) Property, plant and equipment and depreciation

All items of property, plant and equipment are initially recorded at cost. The cost of an item of property, plant and equipment is recognised an asset if, and only if, it is probable that future economic benefits associated with the item will flow to the Society and the cost of the item can be measured reliably.

Subsequent to recognition, property, plant and equipment are measured at cost less accumulated depreciation and accumulated impairment losses. Repair and maintenance costs are recognised in statement of income and expenditure as incurred.

Depreciation on property, plant and equipment is computed on a straight line basis to write-off the cost to its residual value over the estimated useful lives of the assets at following annual rate:-

Information of technology equipments	20%
Office equipment	10%

The carrying values of property, plant and equipment are reviewed for impairment when events or changes in circumstances indicate that the carrying value may not be recoverable.

The residual value, useful life and depreciation method are reviewed at each year-end, and adjusted prospectively, if appropriate.

An item of property, plant and equipment is derecognised upon disposal or when no future economic benefits are expected from its use or disposal. Any gain or loss on derecognition of the asset is included in the statement of income and expenditure in the year the asset is derecognised.

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(b) Impairment of non-financial assets

The carrying amounts of non-financial assets are reviewed at the end of each reporting period to determine whether there is any indication of impairment. If any such indication exists, then the asset's recoverable amount is estimated.

For the purpose of impairment testing, assets are grouped together into the smallest group of assets that generated cash inflows from continuing use that are largely independent of the cash inflows from other assets or cash-generating units.

The recoverable amount of an asset or cash-generating unit is the higher of its fair value less costs to sell and its value in use. In assessing value in use, the estimated future cash flows are discounted to their present value using a pre-tax discount rate that reflects current market assessments of the time value of money and the risks specific to the asset or cash-generating unit

An impairment loss is recognised if the carrying amount of an asset or its related cash-generating unit exceeds its estimated recoverable amount.

Impairment losses are recognised in income and expenditure statement. Impairment losses recognised in respect of cash-generating units are allocated first to reduce the carrying amount of any goodwill allocated to the cash-generating unit (group of cash-generating units) and then to reduce the carrying amounts of the other assets in the cash-generating unit (group of cash-generating units) on a pro rata basis.

Impairment losses recognised in prior periods are assessed at the end of each reporting period for any indications that the loss has decreased or no longer exists. An impairment loss is reversed if there has been a change in the estimates used to determine the recoverable amount since the last impairment loss was recognised. An impairment loss is reversed only to the extent that the assets's carrying amount does not exceed the carrying amount that would have been determined, net of depreciation or amortisation, if no impairment loss had been recognised. Reversals of impairment losses are credited to statement of income and expenditure in the financial year in which the reversals are recognised.

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(c) Financial instruments

(i) Initial recognition and measurement

A financial asset or financial liability is recognised in the statement of financial position when, and only when, the Society becomes a party to the contractual provisions of the instrument.

A financial instrument is recognised initially at the transaction price unless the arrangement constitutes, in effect, a financing transaction. If the arrangement constitutes a financing transaction, the financial asset or financial liability is measured at the present value of the future payments discounted at a market rate of interest for a similar debt instrument.

(ii) Subsequent measurement

Debt instruments that meet the following conditions are measured at amortised cost using the effective interest method:

(a) returns to the holder are determinable, e.g. a fixed amount and/or variable rate of return benchmark against a quoted or observable interest rate;

(b) there is no contractual provision that could result in the holder losing the principal amount or any interest attributable to the current or prior periods;

(c) prepayment option, if any, is not contingent on future events.

Debt instruments that are classified as current assets or current liabilities are measured at the undiscounted amount of the cash or other consideration expected to be paid or received unless the arrangement constitutes, in effect, a financing transaction.

Financial assets or financial liabilities not measured at amortised at cost or cost less impairment are measured at fair value changes recognised in statement of income and expenditure.

PERSATUAN GEOLOGI MALAYSIA
(GEOLOGICAL SOCIETY OF MALAYSIA)
(Registered in Malaysia)

All financial assets are assessed at each reporting date whether there is any objective evidence of impairment. An impairment loss is measured as follows:

(i) For an instrument measured at amortised cost, the impairment loss is the difference between the asset's carrying amount and the present value of estimated cash flows discounted at the asset's original effective interest rate.

(ii) For an instrument measured at cost less impairment, the impairment loss is the difference between the asset's carrying amount and the best estimate of the amount that would be received for the asset if it were to be sold at the reporting date.

(iii) Derecognition

A financial asset or part of it is derecognised when, and only when, the contractual rights to the cash flows from the financial asset expired or are settled, or control of the asset is not retained or substantially all of the risks and rewards of ownership of the financial asset are transferred to another party. On derecognition of a financial asset, the difference between the carrying amount of the financial asset derecognised and the consideration received, including any newly created rights and obligations, is recognised in statement of income and expenditure.

A financial liability or part of it is derecognised when, and only when, the obligation specified in the contract is discharged, cancelled or expires. On derecognition of a financial liability, the difference between carrying amount of the financial liability extinguished or transferred to another party and the consideration paid, including any non-cash assets transferred or liabilities assumed, is recognised in statement of income and expenditure.

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4. GENERAL FUND

	2019 RM	2018 RM
At 1 January	868,937	916,991
Surplus / (Deficit) for the year	42,588	(48,054)
At 31 December	911,525	868,937

5. ENDOWMENT FUND

	2019 RM	2018 RM
At 1 January	1,729,239	1,672,520
Add : Fixed deposits interest income	58,414	56,719
	1,787,653	1,729,239
Less : Transfer to general fund	(50,000)	-
At 31 December	1,737,653	1,729,239

6. AAPG-UM STUDENT CHAPTER FUND

	2019 RM	2018 RM
At 1 January	10,779	10,888
Donation	1,989	1,891
	12,768	12,779
Less : Printing and Stationery	-	133
Refreshment	1,492	867
Travelling	-	1,000
At 31 December	11,276	10,779

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7. DISASTER RESILIENT CITIES KUALA LUMPUR (DRCKL) FUND

	2019 RM	2018 RM
At 1 January	27,099	8,864
Add : Grants received	231,503	407,899
Transfer from National Geoscience Conference	2,061	-
	260,663	416,763
Less : Honorarium	56,500	54,000
Printing	29,280	7,219
Workshop	155,678	326,966
Office expenses	3,574	166
Travelling expenses	-	1,313
Postage	2,077	-
Refreshment	1,827	-
At 31 December	11,727	27,099

8. PROPERTY, PLANT AND EQUIPMENT

	Information technology equipment RM	Office equipment RM	Total RM
Cost			
At 1 January 2019	7,831	133,375	141,206
Additions	-	-	-
Disposal and deletion	-	-	-
At 31 December 2019	7,831	133,375	141,206
Accumulated depreciation and impairment losses			
At 1 January 2019	5,959	120,899	126,858
Charge for the year	373	1,248	1,621
Disposal and deletion	-	-	-
At 31 December 2019	6,332	122,147	128,479
Carrying amounts at 1 January 2019	1,872	12,476	14,348
Carrying amounts at 1 December 2019	1,499	11,228	12,727

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9. FIXED DEPOSITS WITH LICENSED BANK

The fixed deposits with licensed bank have a maturity of between 6 to 15 months (2018 : 6 to 15 months). Interest rates for the deposits ranged from 2.85% to 2.95% (2018 : 2.85% to 2.95%) per annum.

10. TAX EXPENSE

Income tax is provided for investment income and on surplus arising from transactions with non-members. The current tax expense consists of:-

	2019 RM	2018 RM
Current tax:		
On result for the year	132	135
Overprovision in prior year	140	-
	272	135

11. RELATED PARTY DISCLOSURES

(a) Identities of related parties

Parties are considered to be related to the Society if the Society has the ability, directly or indirectly, to control the party or exercise significant influence over the party in making financial and operating decisions, or vice versa, or where the Society and the party are subject to common control or common significant influence. Related parties could be individuals or other parties.

There were no related party transactions during the year.

(b) Compensation of key management personnel

Key management personnel are those persons having the authority and responsibility for planning, directing and controlling the activities of the entity, directly and indirectly, including any Council (whether executive or otherwise) of the Society.

(c) There were no compensation paid to key management personnel during the year.

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12. FINANCIAL INSTRUMENTS

The financial instruments of the Society are categorised into the following classes:

	2019 RM	2018 RM
Financial assets measured at amortised cost less impairment		
Deposits with licensed bank	2,229,701	2,229,701
Cash and bank balances	481,312	481,714
	2,711,013	2,711,415
Financial liabilities carried at amortised cost		
Other payables	47,129	86,211

GSM ENDOWMENT FUND REPORT

GSM ENDOWMENT FUND: BOARD OF TRUSTEES REPORT FOR 54th ANNUAL GENERAL MEETING OF THE GEOLOGICAL SOCIETY OF MALAYSIA
26 June 2020

Background

1. The 47th AGM in 2013 confirmed the establishment of the GSM Endowment Fund and endorsed the Terms of Reference prepared by Advocates and Solicitors, Messrs Yeap, Yong and Amy. The AGM also agreed that the Council obtain "tax deductible" status to encourage donations directly into the "GSM Endowment Fund" and that the interest portion accrued, be used to meet expenses incurred in the implementation of programmes run by the Society.

2. The 48th AGM in 2014 approved an amendment to the Terms of Reference to provide for the establishment of the "Board of Trustees of the GSM Endowment Fund", whose members shall comprise the GSM President, Immediate Past President, Secretary, Treasurer, Editor and at least three independent Full Members "in good standing", to be appointed at the AGM.

3. The 53rd AGM in 2019 was informed that the GSM Council undertook a search on the website of "Lembaga Hasil Dalam Negeri" (LHDN) and found that GSM is listed as an organisation that is approved to collect donations under Subsection 44(6) since the year 1967. The GSM has "tax deductible" status that allows individuals and organizations to obtain tax exemption for their donations (see Appendix A – Screenshot of LHDN website on 16 June 2020).

4. Items arising out of the 53rd AGM held on 29 April 2019 are as follows:
   i. The In-Coming GSM Council is requested to develop an appropriate procedure for issuance of receipts for tax exemption and to inform LHDN for donations of RM 5,000 and above;
   ii. The In-Coming GSM Council to make every effort to transfer some of the fixed deposits in the GSM operating account to the Endowment Fund to increase the principal amount, so as to obtain a higher interest;
   iii. The In-Coming GSM Council is encouraged to have a separate budget line for publications including staff costs, to account for expenses and to facilitate future fund raising activities; and
   iv. The AGM accepted and endorsed the disbursement of RM 80,000.00, to be utilised from the interest accrued in the Endowment Fund, for publications in 2019.

Report of the Board of Trustees

1. This report covers the period from 1 January 2019 to 31 December 2019. The Board of Trustees met virtually via zoom to scrutinise the administration of the GSM Endowment Fund on 16 June 2020. The meeting was moderated by Datuk Fateh Chand. Members in attendance were the Immediate Past President, Dr. Mazlan Madon; President, Abd Rasid Jaapar; Secretary, Dr. Lim Choun Sian; Treasurer, Mr. Ahmad Nizam Hasan; Editor, Prof. Wan Hasiah Abdullah; and GSM Members Dato' Yunus Abdul Razak, Prof. Joy Jacqueline Pereira, Dr. Lee Chai Peng and Mr. Ahmad Said.

2. As requested by the 53rd AGM held on 29 April 2019, the GSM Council increased the principal amount by RM 100,000 in June 2019. The new principal amount, in the form of Fixed Deposits with the United Overseas Bank Malaysia (UOBM) is RM 1,691,999.99.

3. A special operating account is also maintained with UOBM to receive the interest accrued from the principal amount. The interest is kept in this GSM current account at UOBM (which is separate from the operational account of GSM at the Standard Chartered Bank Bhd.). The total interest accrued in 2019 is RM 58,414.00 according to the auditor's report. The total accumulated interest since establishment of the Endowment Fund is RM 145,652.90 as of 31 December 2019.

4. The sum of RM 50,000.00 was transferred to the GSM operational account at the Standard Chartered Bank Bhd. for publications and office space rental in 2019. However, this allocation was approved in 2018. The allocation of RM 80,000.00 requested by the GSM Council for 2019 and approved by the 53rd AGM held on 29 April 2019 was not disbursed.

Recommendations to the 54th AGM of the GSM

The Board of Trustees of the GSM Endowment Fund makes the following recommendations to be considered at the 54th AGM of the GSM to be held on 26 June 2020:

i. The In-Coming GSM Council is requested to make every effort to transfer some of the fixed deposits in the GSM operating account to the Endowment Fund to increase the principal amount, so as to obtain a higher interest;

ii. The In-Coming GSM Council is requested to develop an appropriate procedure for issuance of receipts for tax exemption and to inform LHDN for donations of RM 5,000 and above.

On behalf of the Board of Trustees, I declare that I am satisfied that the GSM Endowment Fund is being administered in a satisfactory manner and that the terms of reference are adhered to. I hereby approve the report prepared for the 54th AGM of the GSM.

Acknowledgement

The Board of Trustees would like to take this opportunity to thank Mr Ahmad Nizam Hasan for his long and dedicated service as the GSM Treasurer.

Datuk Fateh Chand
Chairman
Board of Trustees of the GSM Endowment Fund
Geological Society of Malaysia
16 June 2020

nbaga Hasil Dalam Negeri

Appendix A – Screenshot of LHDN website on 16 June 2020

LHDN MALAYSIA
(index.php)

Portal Rasmi
Lembaga Hasil Dalam Negeri Malaysia

Bersama Membangun Negara
Sel, 16 Jun 2020 **Eng** (bt_goindex.php?bt_kump=2&bt_skum=6&bt_posi=1&bt_unit=8&bt_sequ=1&bt_lgv=2) | **Mal** (bt_goindex.php?bt_kump=2&bt_skum=6&bt_posi=1&bt_unit=8&bt_sequ=1&bt_lgv=1)

(bt_goindex.php) **A+ A A-**

Senarai Institusi Atau Organisasi Yang Diluluskan Untuk Derma Dibawah Subseksyen 44(6) ACP 1967

(i) Garis Panduan Permohonan Untuk Kelulusan Ketua Pengarah Hasil Dalam Negeri Di Bawah Subseksyen 44(6) Akta Cukai Pendapatan 1967 Bagi Tabung Pembelian Rumah Ibadat Bertarikh 8 Jun 2020 (http://www.hasil.gov.my/pdf/pdfam/GP_08062020_PembelianRumahIbadat_1.pdf)

(ii) Garis Panduan Permohonan Untuk Kelulusan Ketua Pengarah Hasil Dalam Negeri Di Bawah Subseksyen 44(6) Akta Cukai Pendapatan 1967 Bagi Tabung Pembinaan Rumah Ibadat Bertarikh 8 Jun 2020 (http://www.hasil.gov.my/pdf/pdfam/GP_08062020_1.pdf)

(iii) Garis Panduan Bagi Kelulusan Ketua Pengarah Hasil Dalam Negeri Di Bawah Subseksyen 44(6) Akta Cukai Pendapatan 1967 Bertarikh 30 Januari 2020 (http://www.hasil.gov.my/pdf/pdfam/GP_44_6_06022020_1.pdf)

(iv) Garis Panduan Bagi Kelulusan Ketua Pengarah Hasil Dalam Negeri Di Bawah Subseksyen 44(6) Akta Cukai Pendapatan 1967 Bertarikh 5 September 2019
(Pindaan subperenggan 6.1(iv)) (http://www.hasil.gov.my/pdf/pdfam/GP_44_6_1_05092019_P.pdf)

(v) Garis Panduan Bagi Permohonan Untuk Kelulusan Di Bawah Seksyen 44(6) Akta Cukai Pendapatan 1967 Bertarikh 15 Mei 2019 (http://www.hasil.gov.my/pdf/pdfam/GP_S44_6_1.pdf)

(vi) Garis Panduan Bagi Permohonan Untuk Kelulusan Di Bawah Seksyen 44(6) Akta Cukai Pendapatan 1967 Bertarikh Januari 2005 (http://www.hasil.gov.my/pdf/pdfam/PermohonanUntukKelulusanDiBawahSeksyen44_6_BM.pdf)

(vii) Garis Panduan Permohonan Untuk Kelulusan Di Bawah Subseksyen 44(6) Akta Cukai Pendapatan 1967 Bagi Tabung Sumbangan Wang Awam Sekolah (http://www.hasil.gov.my/pdf/pdfam/GARIS_PANDUAN_TSUWA.pdf)

(viii) Garis Panduan Permohonan Untuk Kelulusan Di Bawah Subseksyen 44(6) Akta Cukai Pendapatan 1967 Bagi Tabung Pengurusan Ibadat Dan Contoh Peraturan Tabung Pengurusan Rumah Ibadat (http://www.hasil.gov.my/pdf/pdfam/GP_TPRI_FINAL.pdf)

(ix) Senarai Institusi Atau Organisasi Yang Diluluskan Dibawah Subseksyen 44(6) ACP 1967

Dari negeri(Select State): All

16-Jun-20, 10:30

Nama Bermula Dengan Abjad(Name Start With Letter) All

Atau Masukan Nama (Enter Name) : geologi **Cari/Search** **Reset**

Cari Dari Negeri **All** Dengan Nama **geologi....**

	Nama Institusi/Organisasi	Tarikh Kuatkuasa	Sah Sehingga
1	**PERSATUAN GEOLOGI MALAYSIA. (GEOLOGICAL SOCIETY OF MALAYSIA)** D/A JABATAN GEOLOGIUNIVERSITI MALAYA,59100 KUALA LUMPUR.	1967-01-01	

. (bt_goomap.php?cw=0)Ibu Pejabat Lembaga Hasil Dalam Negeri Malaysia, Menara Hasil, Persiaran Rimba Permai, Cyber 8, 63000 Cyberjaya Selangor. . (bt_goindex.php?bt_kump=2&bt_skum=1&bt_posi=1&bt_unit=2&bt_sequ=1)

Paparan terbaik menggunakan pelayar Chrome,Internet Explorer(Versi Terkini) atau Mozilla Firefox dengan resolusi skrin 1280x800. Hak Cipta Terpelihara 2015 © LHDNM

PENAFIAN : Lembaga Hasil Dalam Negeri Malaysia tidak bertanggungjawab terhadap sebarang kehilangan atau kerosakan yang dialami kerana menggunakan maklumat dalam laman ini.

Dasar Privasi (bt_goindex.php?bt_kump=20&bt_skum=1&bt_posi=1&bt_unit=2&bt_sequ=1)

Dasar Keselamatan (bt_goindex.php?bt_kump=20&bt_skum=1&bt_posi=1&bt_unit=3&bt_sequ=1)

Keselamatan *Online* (bt_goindex.php?bt_kump=20&bt_skum=1&bt_posi=1&bt_unit=4&bt_sequ=1)

Peta Lokasi (bt_goomap.php?cw=0)

Peta Laman (bt_goindex.php?bt_kump=3&bt_skum=1&bt_posi=1&bt_unit=4&bt_sequ=1)

OTHER MATTERS

6.1 Formation of IGM-GSM Chapters for Sabah and Sarawak

Submitted by GSM Council 2019/2020

The GSM-IGM Joint Committee Meeting 1/2020 on 15 May 2020 agreed in principal to the setting up an IGM-GSM Chapter for Sabah and an IGM-GSM Chapter for Sarawak.
It was suggested that the Chapters are to be set up based on co-chairmanship from both academia and business/public sector, to be appointed by GSM and IGM respectively. The tenure of each cochairmanship appointment is 2 years.

6.2 Affirmation of Upper Segama Sabah Jurassic and Triassic Granitic Rocks by Radiometric U-Pb Dates

Submitted by Leong K.M.

Further to my past Notes in AOM at GSM AGMs, Jurassic and Triassic U-Pb dates of tonalite in Burton-Johnson *et al.* (2020), with the added statement 'support the previously questioned and excluded 210 Ma K-Ar age of Leong (1974)', have affirmed Upper Segama Sabah Jurassic K:Ar ages of granite, tonalite and hornfels in GS/JMG Kirk (1964, 1968), and GS/JMG Leong (1971, 1974) Triassic 210 Ma K:Ar age of tonalite.

The publications which had dismissed or 'excluded' Sabah Triassic 210 Ma K:Ar age of tonalite of Leong (1971, 1974) and instead had Cretaceous Chert-Spilite Formation or Cretaceous ophiolites or Cretaceous crystalline basement or Cretaceous ophiolite basement as Sabah oldest rocks were Hutchison (1988), Geological Evolution of Southeast Asia (Hutchison, 1989, 1996), Hutchison (1997), Geological Map of Borneo (Tate, 2002), Balaguru *et al.* (2003), Stratigraphic Lexicon of Malaysia (Lee *et al.,* 2004) and Wan Nursaiedah Wan Ismail *et al.* (2014)-(Leong 1998, 1999, 2016). Omang and Barber (1996) had Neogene age for the granitic rocks in Upper Segama Sabah (Leong, 1998). Hutchison (1997) and Tate (2002) had Cretaceous ophiolite basement and Cretaceous crystalline basement as Sabah oldest rocks. Respectively, Hutchison *et al.* (2000), Graves, Hutchison *et al.* (2000) and Burton-Johnson (2013) (Abstract) had Jurassic ophiolite basement as Sabah oldest rocks although Graves, Hutchison *et al.* (2000) results on the granitic rocks in Upper Segama Sabah were 'the acidic rocks belong to the calc-alkaline series and could not have been derived from the ophiolites.'

I appreciate Royal Holloway University of London Professor Dr Robert Hall informing lead author of Burton-Johnson *et al.* (2020), prior to its publication, that Sabah first Triassic 210 Ma K:Ar age of tonalite was published in Leong (1971, 1974) nearly 50 years ago.

Announcement of New Council for 2020/2021

This report contains the results of the election of four (4) council members for the 2-year council member posts that were up for elections after 6 candidates were nominated by members at the end of the nominations period on 30 September 2019 (see earlier report by Nominations Committee, dated 4th October 2019).

The Council on 22 October 2019, appointed Dr Mazlan Madan as the Election Officer, who subsequently co-opted Dr Ng Tham Fatt and Prof Azman Abd Ghani as the scrutineers, in keeping with the procedures laid out in the Constitution.

On 15th November, the council sent out an email notice to members to select four out of the six nominated candidates for those posts, by way of balloting via email to be received by the deadline of 15 December 2019.

At the closing of balloting on 15 December 2019, the following are the results of the voting by members for the four posts of 2-year councillors. Most members returned their ballots on the form given, but some voted by simply replying to the council email. These are still considered valid votes.

No. of members who voted (by returning the ballots via email, as requested): 59

No. of total votes received: 223 (as some members selected less than 4 candidates in their ballots).

The four candidates with the highest number of votes shall be elected to the council;
they are: [in alphabetical order]

- Ahmad Tariq Ahmad Ziyad (51votes)
- Awg Mohd Faizal Awg Mohamad Hamssin (36 votes)
- Maryam Syazana Dzulkefli (39 votes)
- Tan Chun Hock (52 votes)

With the above results, the councillor posts for the term 2020/2021 shall be filled as follows:

President	- Abd Rasid Jaapar
Immediate Past President	- Mazlan Madon
Vice-President	- Ahmad Nizam Hasan
Treasurer	- Lim Choun Sian
Editor	- Wan Hasiah Abdullah
Secretary	- Farah Fazulah Abdullah
Assistant Secretary	- Norazianti Asmari

Councillors (2-year term) [in alphabetical order]
- Ahmad Tariq Ahmad Ziyad
- Awg Mohd Faizal Awg Mohamad Hamssin
- Maryam Syazana Dzulkefli
- Tan Chun Hock

Councillors (for 1-year) [in alphabetical order]
- Joy Jacqueline Pereira
- Nur Iskandar Taib
- Tan Boon Kong
- Yunus Abdul Razak

CERAMAH TEKNIK TECHNICAL TALK

What is geopathic stress?

Mr. Tong Eng Siang
Date: 22 May 2020
Venue: Zoom Apps

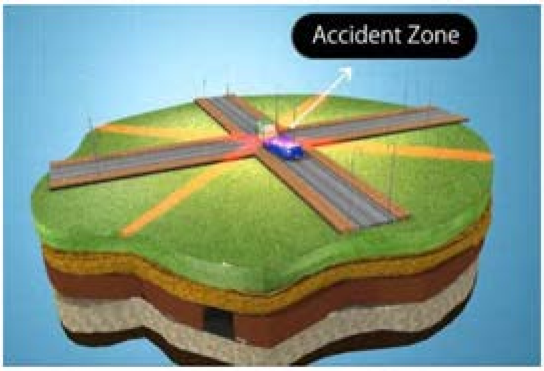
"Geo" comes from the Greek words, meaning of "Earth", and "pathic" comes from 'pathos' meaning disease or suffering. "Geopathic" therefore connotes disease of the earth, "pathology" meaning of all conditions, processes or results of a particular disease.

In simple terms, Geopathology is the study of nature of earthlines, underground water courses, earthfaults and energy vortexes, and their effect on our health and well-being. Geopathic Stress (GS) is a term that includes harmful energies of all kinds, natural grids, earth fault lines and water veins, as well as the detrimental effects on living things that result when the natural frequency of the earth is distorted by natural or certain man- made radiation. The resulting "negative earth energies", as they are often termed, can result in discomfort and even cancer.

Earth is a giant electromagnet; its core produces natural electric currents and magnetic field. This natural Earth Radiation can be distorted by other weak electromagnetic fields — caused by various underground formations such as water veins, natural grids, radioactive mineral deposit, geological fault lines and cavities — as it rises up through the earth.

Geopathic Stress can also result from electromagnetic fields produced by power lines, electrical wiring, lighting, domestic appliances (clocks, computers, microwave sets, radios and TVs), telephones (cellular phones) and power-related equipment (electrical generators, transformers and pylons).

Tree Cancer



Accident Zone

Home/Bed Harmful Energy

Hazard of geopathic stress on human bodies

Geopathic stress suppresses the immune function, shutting down the body's natural defense system, effect of heart rate and blood pressure, thereby facilitating illness/cancer.

The energy emitted by the earth at a specific surface location which affects the normal human body function is termed as Geopathic Stress (GS). Empirical knowledge of the existence of Geopathic Stress is probably as old as mankind.

Geopathic Stress blot out these signals so strongly that the flow of information to the cells, glands and organs is affected or stopped. This has an adverse effect on the body. The stronger the disturbance, the weaker the flow of information and the more marked the symptoms and pains become.

Geopathic Stress has a strong effect on the correct functioning of the lymphatic system. The lymph fluid transports lymphocytes and antibodies, which are continuously patrolling through the body, ready to fight and destroy any foreign cells, such as bacteria, viruses or cancer cells. If the lymphatic system is not healthy, it is unable to destroy foreign cells, thus enabling cancer cells to grow and multiply. In other words, your whole immune system is weakened.

Exposure to Geopathic Stress might initially manifest as a relentless exhaustion; restless sleep or insomnia; persistent headaches; recurrent colds, viral or fungal infections; depression; heightened allergic responses; and the inability to heal or recover from sickness or respond to treatment. The gradual effects of Geopathic Stress and Electromagnetic Radiation can lead to a slow deterioration in the health of individuals who are exposed to such stress. Geopathic Stress is one of the primary causes of serious long-term physical illness and psychological conditions.

Geopathic stress has been found to be the common factor in countless serious – and minor – illnesses, notably those conditions where the immune system is severely compromised: Cancer or chronic fatigue syndrome; eczema and psoriasis; arthritis; migraine or persistent headaches; glandular fever; insomnia; epilepsy; rheumatism; blood disorders and anemia; depression; miscarriage; learning and behavioral problems in children and etc. Studies have shown that Geopathic Stress alters the polarity of the blood, inhibits the blood clotting function, and disrupts electro-chemical activity. It also appears to sensitize the body to various electromagnetic fields of other frequencies.
The pathological effects of Geopathic Stress are not always immediately obvious. They are gradual and more insidious. Initial symptoms may arise in the form of disorders of the immune system or in an inconspicuous illness that recurs after a short time despite successful therapy and with no apparent explanation. If medication and complementary therapies follow a pattern of temporary improvement followed by subsequent deterioration in spite of further medical or therapeutic care, then you should consider the subtle effect of earth radiation as a possible cause. Often, however, at this point damage is extensive and path to recovery may prove long and tedious.

We assume that Geopathic Stress symptoms only have an effect when we expose ourselves to them for prolonged periods on a daily basis. This applies primarily and especially to exposure in the bedroom. When we sleep, we usually relax completely, reducing our body functions to a minimum. This gives the negative effects of earth rays a better chance to influence us. In most cases, these influences manifest as sleep disorders (e.g. restless sleep, insomnia, and frequent waking). Children are particularly susceptible: when they toss and turn in bed, it may be an unconscious effort to find a stress-free place to sleep.

Scientists have observed that it can take up to five years for diseases, such as cancer, to become symptomatic. Anyone who sleep over on GS zone, has a desk job and sits in the same place for six or more hours a day should explore the possibility of harmful earth radiation. This is especially true if he or she feels tired, drained, or exhausted after work, or frequently suffers from headaches or bad luck at the end of the day. Long exposures can lead to serious symptoms and diseases even cancer.

Research by many Scientist around the world while Geopathic Stress does not cause illnesses directly, it may weaken the immune system which in turn weakens the body making it slower to heal and more susceptible to illnesses such as cancer. Sleeping in a Geopathic Stress zone may cause:

- Behavioural problems e.g. aggression, hyperactivity
- Emotional instability - Sleeping disorders and restlessness
- Cancer, M.E. and M.S. (Myalgic Encephalomyelitis and Multiple sclerosis.)
- Aches and pains e.g. headaches
- Learning difficulties
- Sexual difficulties
- Back problems - Infertility and cot deaths
- Asthma and allergies - Depression - Stress and nervousness
- Lack of concentration or memory loss - Nausea - Disorientation - Exhaustion, fatigue or loss of strength

NEW MEMBERSHIP

Student Membership

1. Abdul Aziz Abdul Wahab
2. Abdul Muhaimin Hadzwan Shamsul Raji
3. Abdullah Ab'bas Musa
4. Adeel Hakeem Ahmad Sayuthy
5. Adhwayasya Rizal
6. Adila Fateha Abdul Mudtalib
7. Ahmad Faizal Azhar
8. Ahmad Haikal Mutufarudin
9. Ahmad Mutqma'innah A Razak
10. Ahmad Rieeshi Iman Ahmad Mazri
11. Ahmad Shahrul Zakidin
12. Ainny Farah Anna Yusof
13. Ainyyafiatty Arifin
14. Aishah Norashikin Abdul A'ziz
15. Aleen Syafiqa Azhari
16. Alya Syakirah Tajul Ariffin
17. Alya Syakirah Badros
18. Ameerul Syafiq Muhammad Ensalie
19. Amira Afrina Abdullah
20. Amirul Safwan Mahusin
21. Andi Nurul Izzati Naazira Moharam
22. Angela Vidda anak Chuwat
23. Anis Nabihah Ahmad @ Mohamad
24. Anuar Othman
25. Ariff Loqman Ismail
26. Arina Ismail
27. Astriana Emaonang Sipranus
28. Athirah Syazani Azmi
29. Aurelian Ligunee Jetony
30. Azeem Izharuddin Ahmad Fauzi
31. Azri Sulaimi Safai
32. Azza Malisa Din
33. Balkis Arshilla Kamarul Zaman
34. Camelia Batrisyia Mizamer
35. Che Nursyahirah Che Man
36. Cheok Pei Ying
37. Christabel Peter George Mathew
38. Danites Joel Anyi
39. Darshini Muanindy
40. Darwisa Abd Rahim
41. Dasryl Hanson Darus
42. Divesh P Ragavan
43. Ee Shi Min
44. Eliya 'Aqilah Md Aris
45. Erdiah Ashida Nasirin
46. Erick Naim
47. Erna Nur Shafiqah Esman Faidz
48. Evienstein Wilfred
49. Farah Nabila Ahmad
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IGM Visit to MRT 2 Project Site

IGM organised a visit to the MRT 2 project site at the proposed Chan Sow Lin station on the 28th and 29th November 2019. The visit comprised of two parts. The first is the visit to the Tunnel Control Centre 4 and second is the construction site of Chan Sow Lin MRT station. Total A total of 22 IGM members participated during the two-day visit.

Prior to the briefing, the participants gathered at the Chan Sow Lin site office for a safety briefing. After the safety briefing the participants were showed a slide presentation of the ongoing station construction works. Engineers Naasiha and Rashidah from MMC Gamuda gave a comprehensive talk to the participants. Participants were briefed on the construction challenges including progress, techniques, sequencing and monitoring that are used for building the station. The Chan Sow Lin station has a footprint of 30m X 200m X 40m deep and is one of the largest underground stations that will also have connection to the existing nearby Chan Sow Lin LRT station. The presentation got lively when the geology was discussed with numerous Q&A on site investigation methods that comprised of boreholes, rock probes, grouting records, microgravity and geological mapping. Some participants also shared their experience from other construction projects. Overall, the discussion was good especially for the younger geologists.

The participants then visited the Tunnel Control centre (TC4). The control centre monitors real time the progress of the tunnel boring machine (TBM) that was mining from Chan Sow Lin to TRX station. Over 100 monitoring instruments on the TBM measure different parameters such as TBM thrust force, ground water levels, amount of excavated material and these parameters are fed back to the TBM crew who then make adjustments to the TBM operation. All these parameters are displayed on monitors and the TC4 is manned by 2 tunnel engineers. The briefing at the centre was given by MMC Gamuda tunnel engineer Lim Ji Xiong and tunnel geologist Edwin Cheong Pek Chee (also an IGM member). The briefing was followed by an exciting Q&A session.

Finally, the participants were taken to the viewing platform to see the ongoing station construction works. The immediate Immediate eye-catching structure was the ground anchors along a deep valley that was used to strengthen the rock face. The rock anchors clearly delineated the deep fault zone in otherwise shallow limestone geology. Overall, the visit was very informative and gave a hands-on experience to both the experienced and rookie IGM geologists on the technology used in tunnelling. IGM expresses its appreciation to the management of MMC Gamuda for giving this opportunity.

Reported by:
Devendran Arumugam, P. Geol
Geophysics Working Committee Chairman,
Institute of Geology, Malaysia

Participants on 28th November 2019.

Briefing by MMC Gamuda on station construction.

Briefing at Tunnel Control Centre.

Arial view of Chan Sow Lin station showing deep depression in limestone and ground anchors.

OBITUARY

Innalillahi wa inna ilaihi rojiun
"Indeed, to Allah we belong and to Allah we shall return"
[AlQuran 2:156]

Al-Fatihah buat Professor Madya Dr. Tajul Anuar Jamaluddin

Jasamu pada dunia geologi akan sentiasa dikenang dan dijadikan rujukan.
Semoga rohnya dicucuri rahmatNya.

P.M. Dr Tajul Anuar Jamaluddin merupakan lulusan Sarjana Muda Sains Geologi (1987) dan Sarjana Sains Geologi Kejuruteraan (1990) daripada Universiti Kebangsaan Malaysia Bangi, dan Doktor Falsafah Geologi Struktur (1997) daripada University of Wales Aberystwyth, United Kingdom.

Beliau pernah berkhidmat sebagai tutor sementara di Universiti Kebangsaan Malaysia (1987 - 1990) dan juga buat seketika sebagai engineering geologist di Malaysia International Consultant (1990). Seterusnya, beliau telah berkhidmat sebagai tutor SLAB (1991-1997) dan pensyarah (1997-2006) di Jabatan Geologi, Universiti Malaya, di mana beliau telah dilantik sebagai Professor Madya pada tahun 2004.

Beliau kemudiannya berhijrah ke Jabatan Geosains & Petroleum Geologi, Universiti Teknologi PETRONAS pada Jun 2006 dan telah berkhidmat di sana sehingga Februari 2007.

Bagai sireh pulang ke gaganng, beliau kemudian berkhidmat pula kepada Universiti Kebangsaan Malaysia menerusi Program Geologi dan SEADRI/LESTARI bermula daripada Mac 2007 sehingga ke akhir hayat beliau.

By Norazianti Asmari

UPCOMING EVENTS*

September 23-24, 2020: AAPG/EPF Energy Opportunities; Mexico City. Further details can be obtained at https://energyopportunities.info/2020/.

September 29 - October 1, 2020: AAPG Annual Convention and Exhibition (ACE) - Online and on-demand through the end of the year. Visit https://ace.aapg.org/2020/ to obtain more details.

September 30 - October 2020: GeoGulf 2020 (70th GCAGS/GCSSEPM convention and exposition); Lafayette, Louisiana. Visit http://www.geogulf.org/ to obtain more details.

October 11-16, 2020: SEG2020 International Exhibition and 90th Annual Meeting, Houston, Texas, USA. Further details at https://seg.org/AM/2020/.

November 2-6, 2020: Offshore Tecnology Conference Asia (OTC Asia) -virtual. For further information, contact otcasia@otcnet.org or visit 2020.otcasia.org.

November 25-26, 2020: International Conference on Earth Sciences and Environment (ICEMEN 2020), via online conference platform. For details about the conference, please contact the secretariat at icemen2020@ukm.edu.my or contact +603-89214691.

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

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

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.

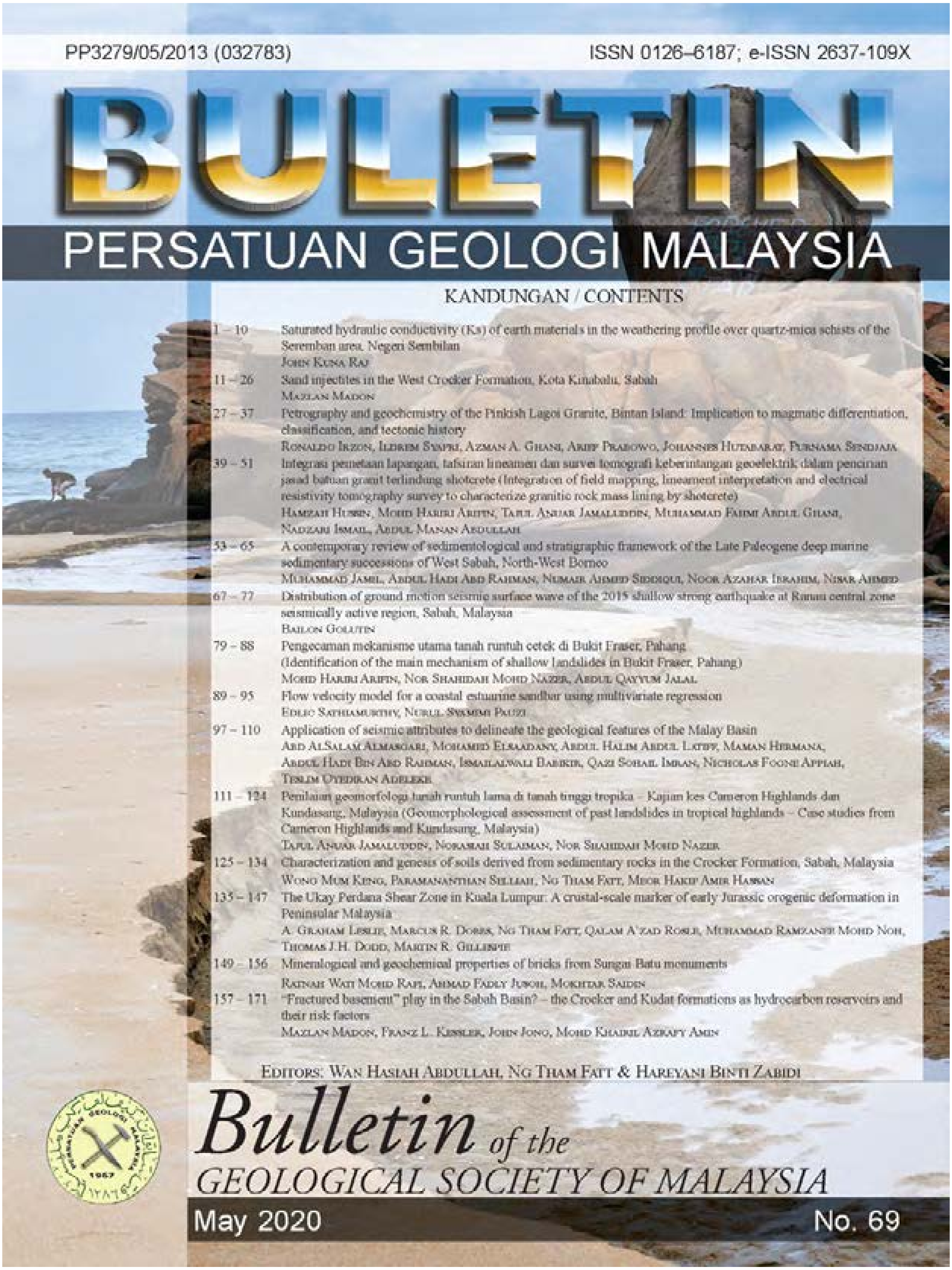
May 4-6, 2021: Myanmar Oil & Gas Conference; Yangon, Myanmar. More information can be obtained at https://eage.eventsair.com/fifth-aapg-eage-myanmar-conference/.

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.

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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