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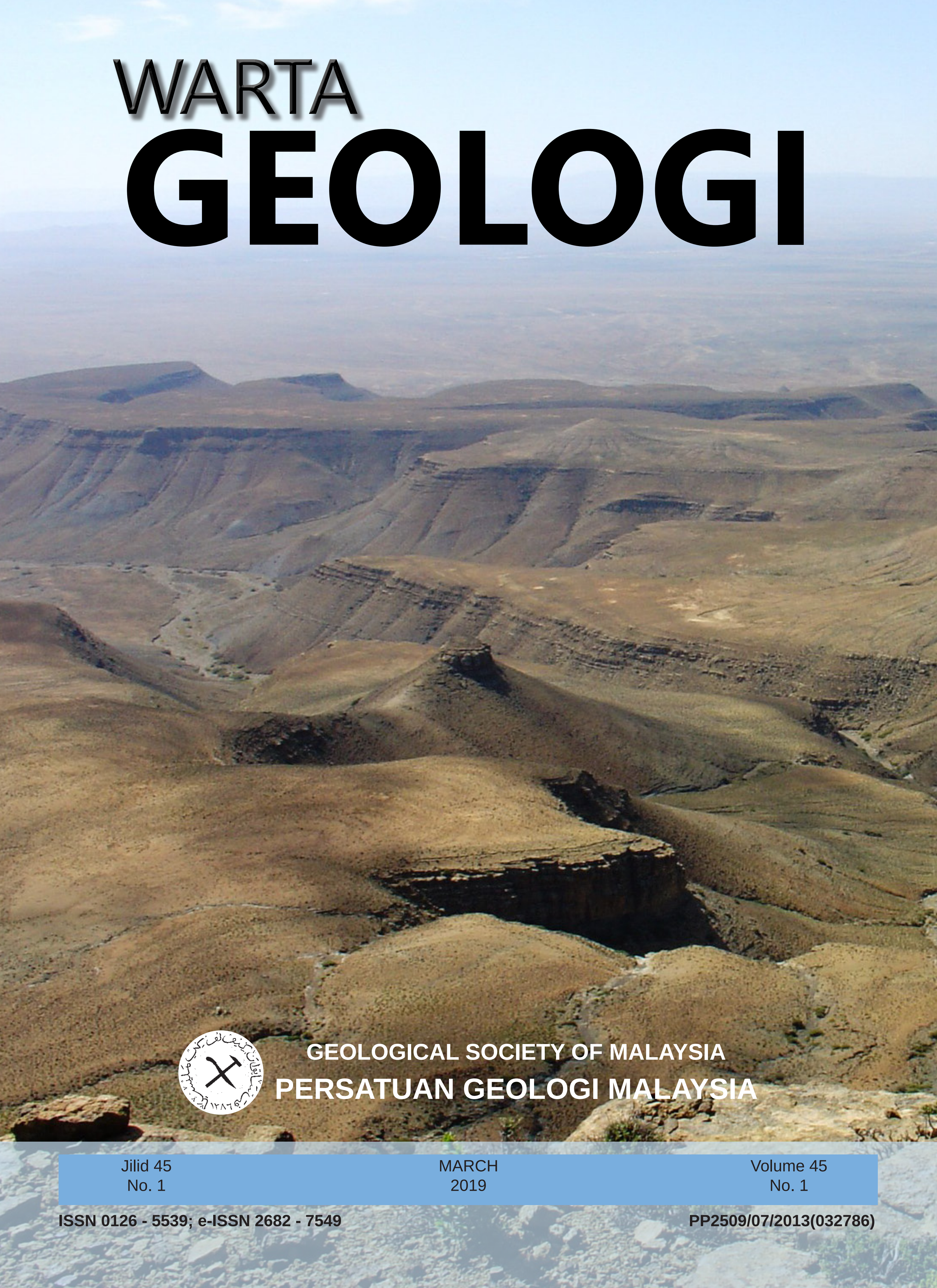

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Cover photo: View north from the peak of Skoorsteenberg mountain (elevation ~1200 m above sea level), South Africa, overlooking the Tanqua subbasin, where flat-lying turbidite sequences belonging to the Permian Tanqua Submarine Fan Complex of the south-western Karoo Basin are well-exposed to become one of the best-studied turbidite fan complexes. Photograph by Mazlan Madon, September 2003.

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Application of sand percentage to evaluate fault seal risk

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Abstract: In hydrocarbon exploration, establishing Allan Sections, calculating Shale Smear Factor and Shale Gouge Ratios are the few commonly applied methods for assessing fault seal risk. In this paper, an alternative approach is introduced to evaluate seal risk at the prospect scale by overlaying a sand percent map over the prospect structure map to help quantify seal risk along the fault trace. This approach effectively integrates all G&G data readily accessible to an interpreter during a prospect maturation process to narrow the seal risk uncertainty.

Keywords: Allan Sections, fault seal, sand percent, Shale Smear Factor, Shale Gouge Ratios

INTRODUCTION

Industry has traditionally relied on three methods to assess fault seal risk, Allan Sections (Allan, 1989), Shale Smear Factor (Smith, 1966, Weber *et al.*, 1978, Lindsay *et al.*, 1993), and Shale Gouge Ratios (Yielding *et al.*, 1997). This paper will introduce a fourth method to evaluate seal risk using sand percent.

We will briefly review the use of Allan Sections and Shale Smear Factors to evaluate seal risk, and include a more thorough discussion of Shale Gouge Ratios since the sand percent method is a derivative of the Shale Gouge Ratio method. We will then discuss the application of sand percent to evaluate seal risk.

Several studies have shown that traps have a tendency to leak when the Shale Smear Factor is less than 3 and the Shale Gouge Ratio is less than 0.2. Conversely, traps are likely to work when the Shale Gouge Ratio is 0.4 or greater (Broussard & Lock, 1996, Bretan *et al.*, 2003, Kessler & Jong, 2018).

ALLAN SECTIONS

The use of Allan Sections is based on the assumption that the fault itself has no sealing properties; the fault is not an open conduit; and the trapping and migration relationships at a fault depend upon the juxtaposition of sands across the fault (Allan, 1989). Impermeable beds juxtaposed against permeable beds are assumed to seal in structural closure whereas permeable beds juxtaposed against permeable beds allow hydrocarbons to spill across a fault. To assess the cross-fault juxtaposition relationships, cross sections are constructed along the hanging wall and the footwall of a faulted structure (Figure 1).

Allan Sections allow interpreters to see the relationship of the footwall stratigraphy relative to the hanging wall stratigraphy to assess the risk of cross-fault leakage. However, the assumptions listed by Allan (1989) are not universally true; there are a number of fields in which there are hydrocarbons tapped in fault blocks that are juxtaposed across from permeable horizons. As such, interpreters must use caution when using Allan Sections to assess seal risk. Nonetheless, it is generally true that the more permeable layers a horizon is juxtaposed across, the higher is the seal risk.

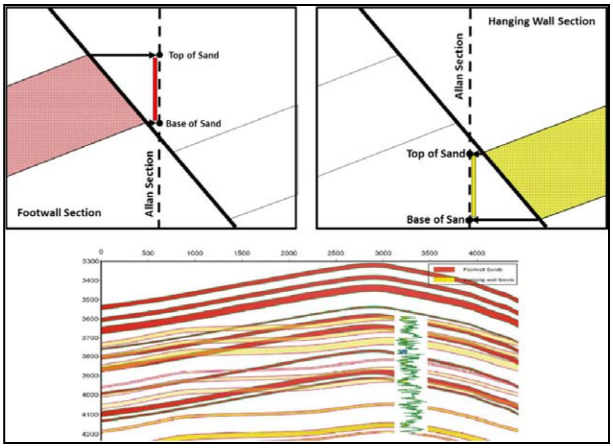

Figure 1: The Allan Section is a cross section constructed through the fault gap. The footwall and hanging wall horizons are projected on to the cross section normal to the section. When the footwall and hanging wall sections are displayed together we can see where permeable beds of the hanging wall are juxtaposed across the fault from permeable beds in the footwall (modified from Tearpock & Bishske, 2003).

SHALE SMEAR FACTOR

Shale Smear Factor (SSF) was first described by Smith (1966). He noted that clay was often smeared along the fault zone and that the smeared clay would inhibit fluid migration across the fault (Figure 2). The SSF is determined by dividing the fault throw by the thickness of the shale layer (Lindsay *et al.*, 1993).

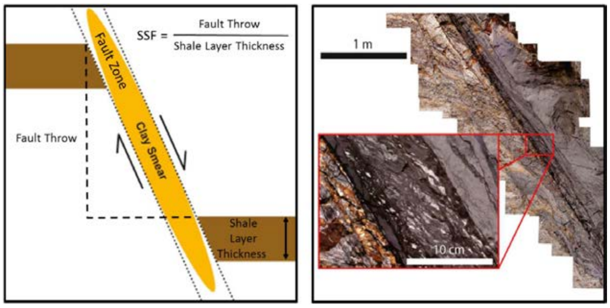

Figure 2: The Shale Smear Factor is a measure of the amount of clay material smeared along a fault zone (Smith, 1966). Clay smear observed in a fault zone near the city of Miri in Sarawak Malaysia (Vrolijk *et al*., 2015).

SHALE GOUGE RATIOS

Yielding *et al*. (1997) defined Shale Gouge Ratio (SGR), which is simply the percentage of shale or clay in the slipped interval. The more shaley the wall rocks, the greater the proportion of shale in the fault zone, and therefore the higher the capillary entry pressure (Yielding *et al*., 1997). More simply stated, the SGR is equal to the net shale in the interval offset by the fault (Figure 3).

OUTCROP AND SUBSURFACE SHALE GOUGE RATIO INVESTIGATIONS

The greater Miri area offers particularly well-exposed, world-class examples of fault geometry and clay gouging (Figures 4 and 5). Such information offers good material for studying fault architecture and clay smear morphology, and help to understand fault seal mechanisms in the subsurface (Kessler & Jong, 2017a & b). Field measurements of fault throws suggest that small fault throws result in thin layers of clay gouging, whereas large fault throws offer thick layers of clay smear (Figure 5). Such data can provide important analogues for predicting, or to simulating pressure and retention of hydrocarbon columns (Kessler & Jong, 2018).

In a recent study by Kessler & Jong (2018), it can be observed that within sand-prone shallow marine to intertidal settings, and a SGR of 0.1 to 0.2, fault sealing can be highly dependent on gouge texture, but in most cases commercial quantities of hydrocarbons cannot be retained with the resulting short hydrocarbon columns (Figure 6). On the other hand, within shale-dominated settings, such as the Sabah deepwater area, fault sealing capacity is high with SGRs mostly above 0.5. Furthermore, sand-to-shale juxtaposition along fault is more likely and leading to a high probability of retention (Figure 6).

This study indicates that for traps with a SGR of less than 0.20 traps rarely work. The traps that do work generally have column heights less than 50 feet. For traps with a SGR between 0.20 and 0.4, traps can work. Column heights range from negligible to 250 feet, but are mostly less than 50 feet. Traps having an SGR greater than 0.4 commonly work and often exhibit column heights greater than 200 feet. These results are similar to those observed by Broussard & Lock (1996), Yielding *et al*. (1997) and Bretan *et al*. (2003).

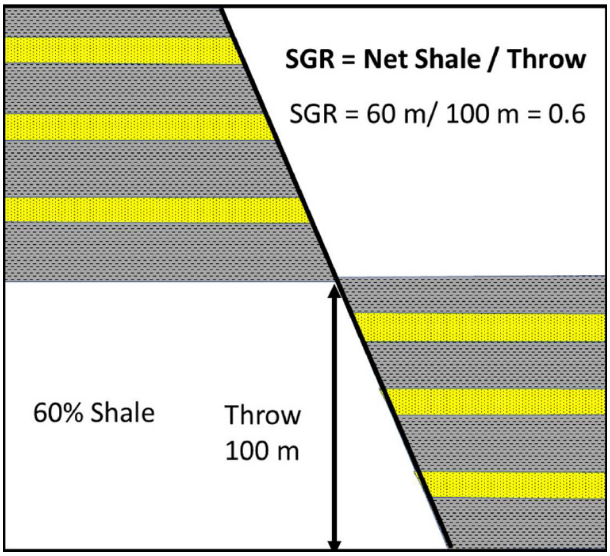

Figure 3: The Shale Gouge Ratio is equal to the net shale in the interval offset by the fault, i.e. net shale/throw.

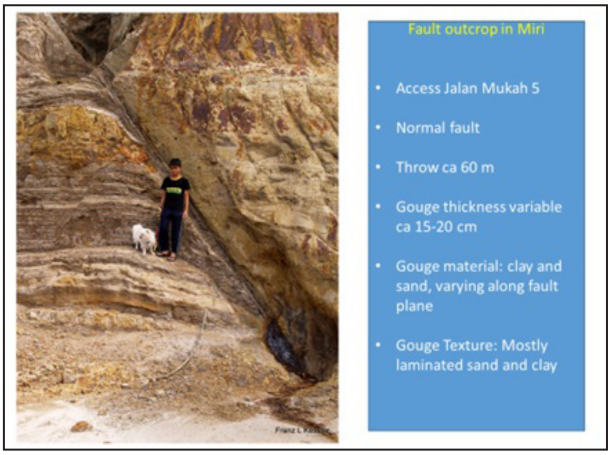

Figure 4: A normal fault on Miri's Canada Hill showing variable gouge material and texture with an estimated Shale Gouge Ratio of 0.3.

SAND PERCENT FOR RESERVOIR PREDICTION

Sand percent maps, alternatively known as Sand-to-Shale Ratio Maps or Net-to-Gross Maps, are a portrayal of the percentage of either total sand or net sand in a given gross interval. Sand percent maps have long been used to predict reservoir as they provide the interpreter with a map that illustrates the distribution of sand across the study area. The distribution of facies within clastic depositional systems is well understood from outcrop and modern depositional environment studies. This understanding can be used to generate sand percent maps even when there is limited well control.

When defining exploration play fairways, sand percent maps can be used to delineate the exploration sweet spot

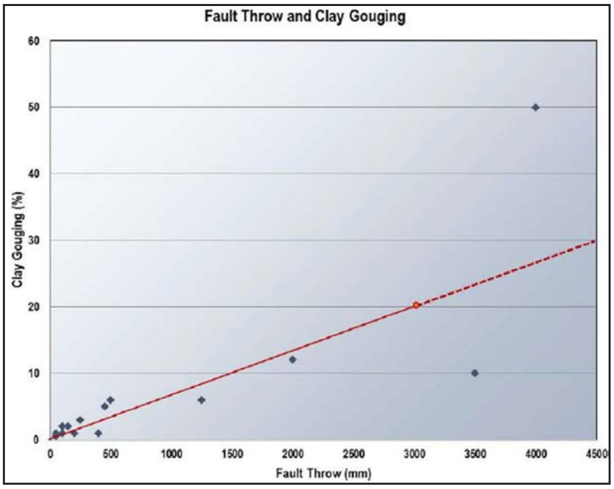

Figure 5: Measurements of clay gouging and fault throw taken from the shallow marine Neogene sedimentary outcrops located in Miri. Small fault throws result in thin layers of clay gouging, whereas large fault throws offer thicker layers of clay smear. Note the lack of data points for fault throws of more than 2000 mm resulted in an unreliable trend line for throw values of more than 3000 mm. However, this trend may be substantiated with more data, and may be useful to predict potential hydrocarbon columns in fault-traps (Kessler & Jong, 2017a & 2017b).

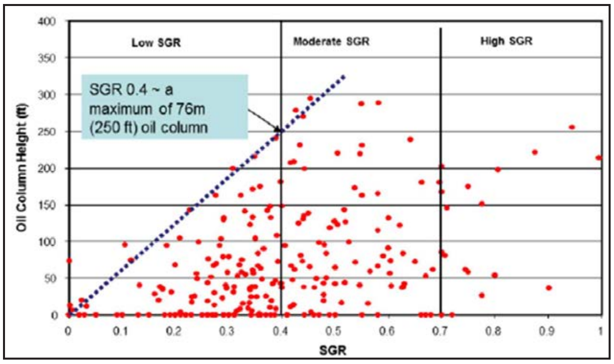

Figure 6: Oil column length (feet) versus SGR based on data compiled by Shell.

(Figure 7). Reservoir risk increases in a downdip direction and seal risk increases in an updip direction. The play fairway lies between sand percent values of 7 or 70%. The play sweet spot is between 20 and 50%.

SAND PERCENT FOR SEAL PREDICTION

As we can see in Figure 7, we can use sand percent to help define seal risk in the play fairway scale. We can also use sand percent to help define seal risk at the prospect scale by overlaying a sand percent map on to the prospect structure map (Figure 8).

Where high sand percent values (>60%) intersect the fault, seal risk is high. Where sand percent values between 20 and 60% intersect the fault, seal risk is moderate, and where low sand percent values (<20%) intersect the fault, seal risk is low.

The application of this method can be illustrated for a prospect in the Texas Gulf Coast where two wells have been proposed to test Frio A and B reservoirs. The Frio B

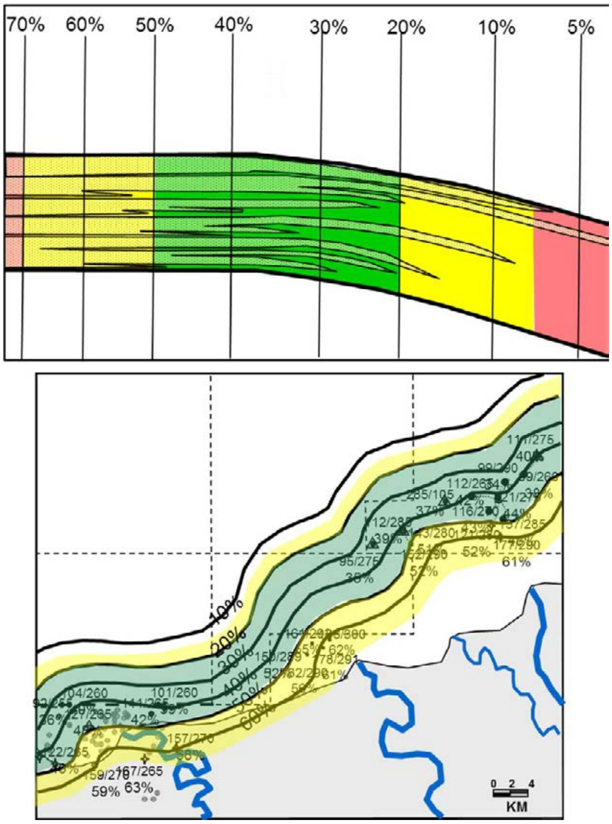

Figure 7: Sweet spot definition and play fairway map for a deltaic sequence. Where sand percent values are too low reservoir risk is high. Where sand percent values are too high seal risk is high. This means there is a reverse probability correlation between reservoir and seal.

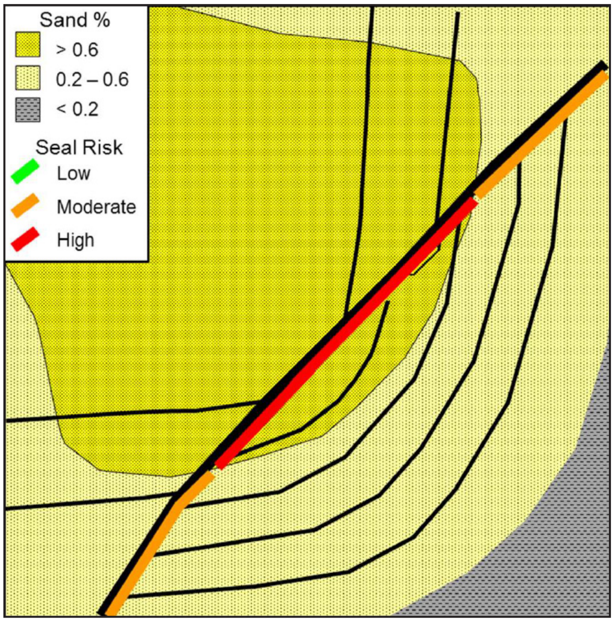

Figure 8: Sand percent map overlain with a depth structure map. Where high sand percent values (>60%) intersect the fault, seal risk is high. Where sand percent values between 20 and 60% intersect the fault, seal risk is moderate. Where low sand percent values (<20%) intersect the fault, seal risk is low.

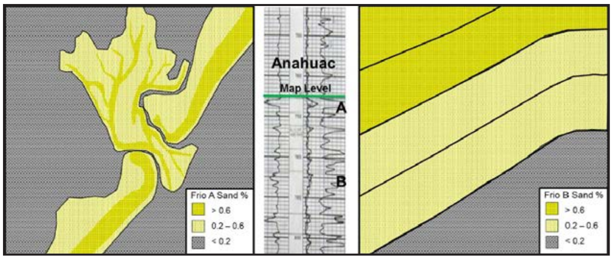

Figure 9: Sand percent maps for the Frio A (Left) and the Frio B (Right). The map level for the structure map seen in Figures 10 and 11 is the top of the Frio A. The Frio A was deposited in a barrier island and tidal delta environment. Frio B was deposited in a coastal strandplain just southwest of a wave-dominated delta. The Frio is overlain by the thick Anahuac Shale.

was deposited in a coastal strandplain and wave-dominated delta striking northeast to southwest (Figure 9). The Frio A is characterised as a barrier island and tidal delta sequence that formed when the Frio B was transgressed (Figure 9). The Frio A is overlain by the Anahuac Shale, which is over 500 feet thick in this location.

Looking first at the proposed Location 1, the trap is rollover anticline with a portion of the trap comprising a downthrown fault closure. The offset along the fault is such that the Frio A in the downthrown block is juxtaposed across from the Frio B in the upthrown block. To properly assess the seal risk, the Frio B sand percent map is overlain in the upthrown block and the Frio A sand percent map overlain in the downthrown block (Figure 10). The juxtaposition of the Frio A against Frio B sand percent values of 20 to 60% resulted in a moderate seal risk.

The trap for Location 2 is an upthrown fault closure. The offset along the fault is such that the Frio A in the upthrown block is juxtaposed across from the Anahuac Shale such that the seal risk is low (Figure 11).

One advantage of using sand percent maps to assess seal risk is that it also provides a map of the reservoir which can be used to plan exploration and development wells. It is possible to construct reasonably accurate sand percent maps ahead of the drill bit so long as the interpreter knows the depositional environment.

CONCLUSIONS

In hydrocarbon exploration, predicting fault seal risk for an effective trapping mechanism is as much an art as science. There are a few common methods established to assess fault seal risk, including Allan Sections, Shale Smear Factor and Shale Gouge Ratio, each with its own advantages and short-falls. In this paper we introduced an alternative approach for evaluating seal risk at the prospect scale by combining a sand percent map with the prospect structure map to help quantify seal risk along the fault trace. This approach integrates seismic, well, core analysis petrophysical parameters and field observations; data which are readily available to an interpreter during a prospect maturation process to lower the seal risk uncertainty.

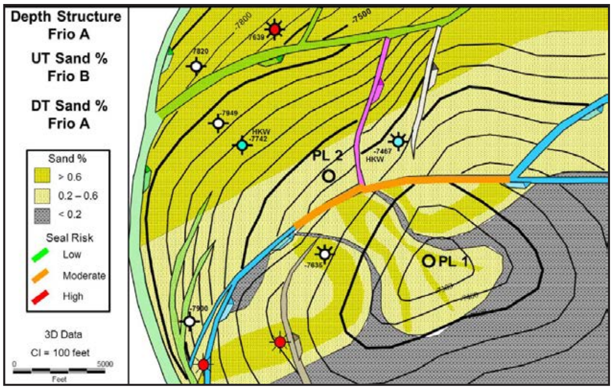

Figure 10: Overlay of the Frio A sand percent in the downthrown block and the Frio B sand percent in the upthrown block to assess seal risk for prospect location 1. Frio A sand percent of 40% and higher are juxtaposed against Frio B sand percent values or 40 to 60%, making the seal risk for location 1 moderate.

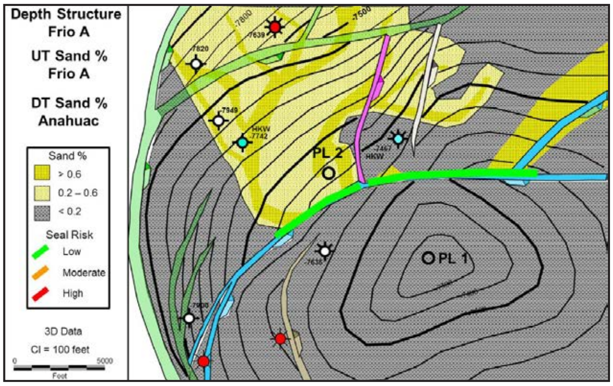

Figure 11: Overlay of the Frio A sand percent in the upthrown block and the Anahuac Shale sand percent in the downthrown block to assess seal risk for prospect location 2. Frio A sand percent of 40% and higher are juxtaposed against shale, making the seal risk for location 2 low.

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Sedimentology facies of the Tatau Formation, Tatau-Bintulu Road transact, Sarawak, Malaysia

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Abstract: Sarawak is divided into four zones, namely the West Borneo Basement, Kuching Zone, Sibu Zone and Miri Zone. The Sarawak Basin in the state covers both onshore and offshore areas, divided into several geological provinces which are of Palaeogene to recent age. On the shelf of the basin, sedimentary succession exceeds 12 km thick (Tan & Lamy, 1990). The study area which is located between Tatau and Bintulu, consists of sediments which are Neogene in age. Sedimentology and stratigraphy study was carried out on the Neogene sedimentary succession at the study area, which stretches around 10 km to 15 km northeast of Tatau town and southwest of Bintulu town. A total of four outcrops were studied. The results are based on field survey of the outcrops across the study area and laboratory analysis of the collected sedimentary samples from the field. The facies analysis results in the identification of seven facies which can be are sand-dominated facies and mixed sand and mud-dominated facies. The sedimentary successions were deposited in an estuarine-inner shelf region.

Keywords: Sarawak basin, early Neogene, Miri Zone, Tatau Formation

Abstrak: Sarawak dibahagikan kepada empat zon iaitu West Borneo Basement, Zon Kuching, Zon Sibu dan Zon Miri. Lembangan Sarawak dibahagikan kepada beberapa wilayah geologi yang berumur Paleogen sampai sekarang, meliputi kedua-dua kawasan di dalam dan luar pesisir. Di pelantar lembangan, ketebalan sedimen melebihi 12 km (Tan & Lamy, 1990). Kawasan kajian yang terletak di antara Tatau dan Bintulu terdiri daripada sedimen yang berusia Neogene. Kajian sedimentologi dan stratigrafi telah dijalankan di kawasan kajian yang terbentang di sekitar 10 km hingga 15 km timur laut dari bandar Tatau dan barat daya dari bandar Bintulu. Sebanyak empat singkapan telah dikaji. Keputusan adalah berdasarkan kajian di singkapan dalam kawasan kajian dan analisis di makmal menggunakan sampel yang dikumpul. Melalui analisis fasies, tujuh jenis fasies telah dikenal pasti di mana fasies tersebut boleh dikategorikan sebagai fasies yang didominasi oleh pasir dan fasies yang didominasi oleh pasir dan lumpur. Sedimen telah dienapkan di kawasan muara-dalaman.

Kata kunci: Lembangan Sarawak, Neogene awal, Zon Miri, Formasi Tatau

INTRODUCTION

The Sarawak Basin exhibits a complex geology and there has been insufficient sedimentological data for interpretation. Although many earlier studies have been carried out since the early 50's, the understanding of the geological and tectonics history of Sarawak is still unclear (Tongkul, 1999). This study tends to focus its attention to the Neogene sedimentary rocks around Tatau area which is less explored. Existing regional geological information of the area can be obtained from some previous studies, but there have been numerous good sedimentary rock exposures throughout the years (Tongkul, 1999). Hence, there is a need to re-examine the early geological evolution of the area.

The focus of this study is the site situated on the northeastern part of the Tatau area, onshore between Tatau town and Bintulu town of Sarawak. In this study, emphasis is on the sedimentology and stratigraphy (facies) of the study area. This research documents the types of sedimentary rocks or facies, sedimentary layers and illustrates the stratigraphic architecture of the area.

The main objective of this study is to reconstruct the depositional history of the early Neogene Sarawak Basin, to reveal the types of deposited sediments and their sequence of deposition. The specific objectives of this study are: (1) to reveal the successions of sedimentary facies, (2) to deduce the facies associations in the formation and (3) to determine the depositional environment of the study area.

GEOLOGICAL SETTING AND STUDY AREA

Geological setting of Sarawak

According to various geological histories, Sarawak is divided into four zones including the West Borneo Basement, Kuching Zone, Sibu Zone and Miri Zone. In the Kuching Zone, most of the zone is cropped out by Paleozoic and early Mesozoic rocks. Most of the rocks in the central and northern part of Sarawak are of Late

Mesozoic and Cenozoic age. In the Sibu Zone, the rocks are almost Upper Cretaceous to Upper Eocene in age. The Miri Zone is the youngest zone, underlain by Upper Eocene to recent strata. From Kuching to Miri zone, there is a decrease in stratigraphic and structural complexity towards the east.

The West Borneo Basement is the eastwards extension of Sundaland. It is the pre-Tertiary continental core of Borneo with the Middle Jurassic to Late Cretaceous plutonic rocks intruding the oldest rocks of Middle-Upper Carboniferous to Permian basement rocks. Hutchison (1989, 1996) summarized the geology of the West Borneo Basement. Middle-Upper Carboniferous to Permian mica schists, hornfels and metaquartzites are the oldest rocks in the zone. The Middle Jurassic to Late Cretaceous plutonic suites intruded these rocks.

Kuching Zone, located at the southwestern part of Sarawak, is believed to be the northward extension of the West Borneo Basement (Hutchison, 1989). This zone consists of sub-Upper Cretaceous shelf deposits where the central region of Kuching which consists of marine limestones is overlain mainly by siliciclastic sequences and minor carbonates. The Lupar line marks the boundary between Kuching Zone and Sibu Zone. This zone is overlain by interbeds of deep-sea sediments and pillow basalt and intruded by gabbro.

Deepwater sediments of the Rajang Group which have been deformed into the Rajang Fold-Thrust Belt underlie The Sibu Zone. Lupar, Belaga and part of Danau Formation are part of Rajang Group (Hutchison, 1996). The zone consists of intensely folded, thrust and low-grade metamorphosed turbidites of Late Cretaceous to Eocene age (Haile, 1969). The Tatau-Mersing Line separates the Sibu Zone and Miri Zone. According to Hutchison (1989), the structurally complex zone consists of Paleocene to Eocene ophiolitic rocks.

Further to the north and east, shallow marine shelf sediments dominate the Miri Zone. This structurally complex zone is dominated by Palaeocene to Eocene ophiolitic rocks (Hutchison, 1989). Some of the rocks are basalt, tuff and radiolarian chert. The Tatau-Mersing Line is a major unconformity between the Rajang Group and the Upper Eocene-Recent sediments of the Miri Zone that overlie the group. Rocks in this zone represent the lower part of the Sarawak Basin succession which prolongs offshore into the continental margin.

Study area

Figure 1 shows the location of the study area. The study area is located between Tatau and Bintulu (along Tatau-Bintulu Road). A total of four outcrops were studied (Figure 1).

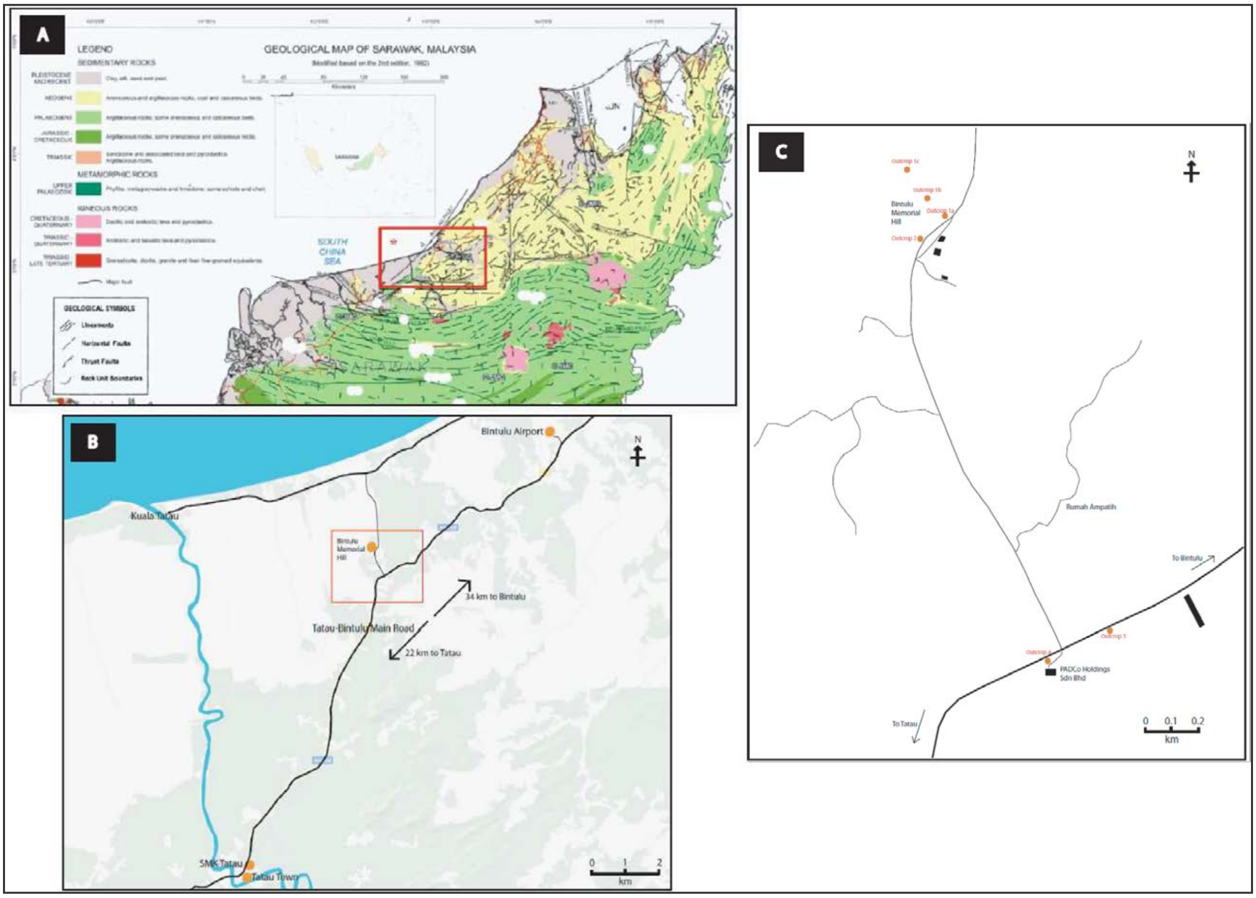

Figure 1: A – Geological and structural map of Sarawak; B – Location map of study area; C – Location of outcrops (1a, 1b, 1c, 2, 3 and 4).

Deposition and deformation of Sarawak young from west to east and south to north. The central part of Sarawak (Miri Zone) is deposited by several rock units, the oldest Lupar Formation, followed by Belaga Formations, Tatau, Buan and Nyalau Formations. Due to the lack of precise age indicators, the stratigraphical relationships between the formations have not been abundantly justified.

The extensive outcrops along in the vicinity of Tatau exhibit a variety of complex structures (Tjia *et al*., 1987). According to Tjia *et al.* (1987), the lithology and tectonic deformation of the Early Tertiary sediments in Tatau area was interpreted to have occurred in a for-arc basin on the ocean side of a magmatic arc. Based on the stratigraphy of Miri Zone, the study area is believed to be closely related to Tatau Formation and Buan Formation. Tatau and Buan Formations are younger formations that surround the oldest formation in Tatau area, Belaga Formation. Both the formations were deposited under shallow marine to non-marine conditions.

The Tatau Formation (Upper Eocene to Oligocene) is made up of moderately to strongly folded rock units, probably uncomformable on Belaga Formation. It consists of medium to fine-grained sandstones and shale with intervals of marls and limestone lenses (Wolfenden, 1960). There are as well presence of argillite and slate. The formation was deposited in littoral to neritic environment. It composed of coarsening upwards heterolitic beds.

Evidence from previous studies indicated the presence of fossils in the Tatau Formation (Wolfenden, 1960). In the Tatau Formation, limestone contains a rich fauna of Foraminifera. The limestone containing Foraminifera is Eocene and Oligocene in age. There are as well presence of rare gastropods, corals, echinoids fragments and calcareous green and red algae in the limestone. Marls of the same age of the Tatau Formation contain pelagic Foraminifera.

METHODOLOGY

A total of four outcrops (Figure 2) were studied where two outcrops are at Bintulu Memorial Hill and the other two along the Tatau-Bintulu main road (at the right from Tatau). Six exposed localities were logged with emphasis on: (i) lithology, (ii) bed thickness, (iii) bed contact, (iv) sedimentary structures, (v) fossil content and (vi) bioturbation style. Figure 3 shows the sedimentary log for Outcrop 3 which is located along the Tatau-Bintulu main road. Records were produced in three common forms: field notes, drawings and photographs and graphic logs. Further laboratory work such as petrography analysis were carried out with samples collected from the field.

RESULTS AND INTERPRETATION

Seven sedimentary facies which can be categorized into sand-dominated facies or mixed sand and mud-dominated facies have been recognized. Types of facies include:

F1 - Massive sandstone

F2 - Laminated sandstone

Figure 2: A total of four outcrops were studied. (a) Outcrop 1a with a total thickness of 3.25 m. (b) Outcrop 2 with a total thickness of 3.75 m. (c) Outcrop 3 with a total thickness of 15.5 m. (d) Outcrop 4 with a total thickness of 3.96 m.

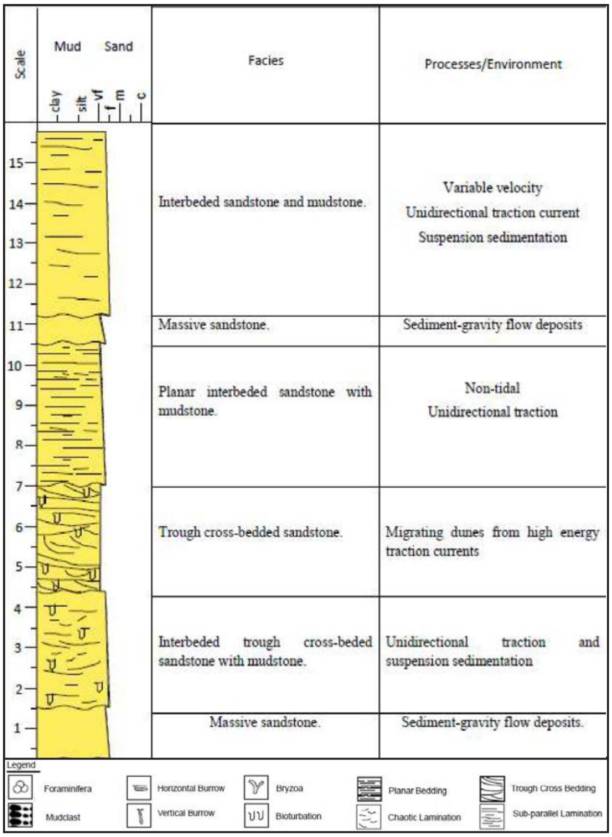

Figure 3: Sedimentary log for Outcrop 3.

F3 - Amalgamated sandstone
F4 - Trough cross-bedded sandstone
F5 - Interbeded siltstone/mudstone and sandstone
F6 - Heterolthic mudstone/siltstone
F7 - Heterolithic sandstone

1) F1: Massive sandstone

Lithology and geometry

This facies is present in all the outcrops in the study area. It is light grey in colour, with good to moderate sorting and normal grading in grain size. The grain sizes of massive sandstone in all the outcrops are mainly very fine to fine/medium. Some of the F1 beds appear to be very thin like 0.01 m but the thickest F1 beds can be 3 m. Although most of the massive sandstones are soft, few beds are hard and less weathered. The facies has locally erosive or irregular upper and basal contact. It is often overlain by lamination or interbeds of siltstone or mudstone. F1 shows good lateral continuity across the whole outcrop.

Sedimentary structures

The massive sandstone beds are often structureless or may sometimes be internally graded upward into thin laminated sandstone with faint horizontal stratifications. There are existence of granules and intra-clasts such as mudclasts (Figure 4a). The mudclasts are usually moderately well-rounded and spherical; develop at the

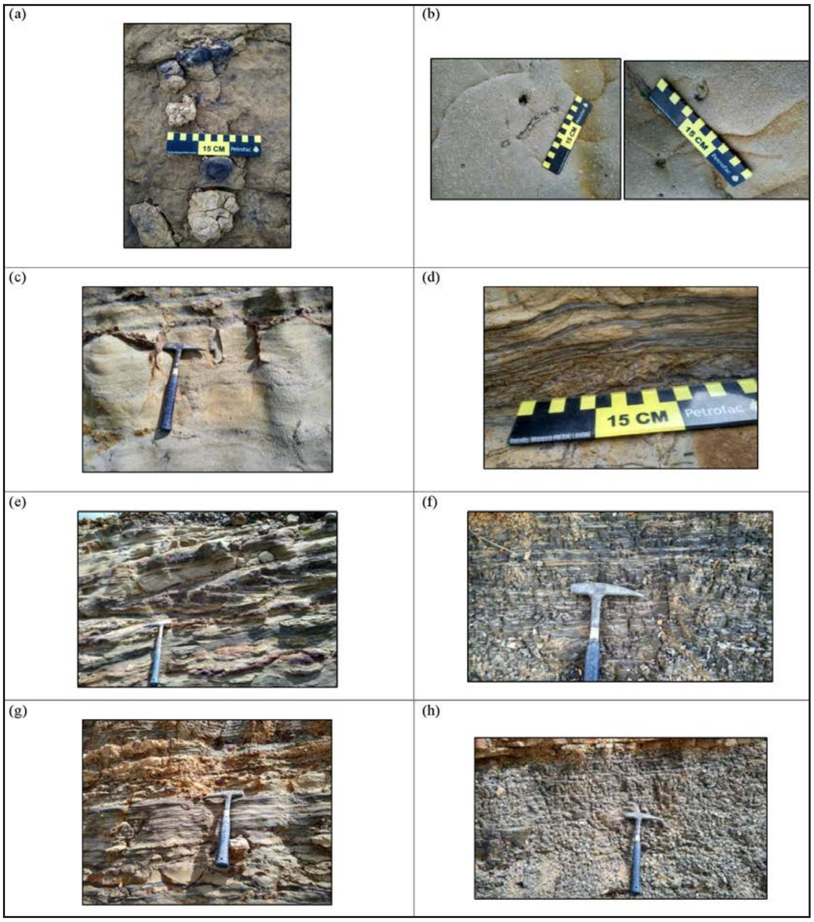

Figure 4: Main characteristics of facies. (a) Mudclasts (moderately well rounded and spherical). (b) Trails and tracks. (c) Laminated sandstone. (d) Skolithos (?) trace fossils and traces of plants. (e) Trough crossbedded sandstone. (f) Interbedded siltstone/mudstone and sandstone (lenticular). (g) Irregular and wavy stratification. (h) Heterolithic siltstone/mudstone.

bottom or towards the upper part of the beds. The thicker F1 beds can be of the same grain size, coarsening upwards or fining upwards. In the section with finer grains, structure such as climbing ripple lamination can be observed. Flame structure can as well be identified at the base of some beds due to the loading of this F1 facies on the top of weaker mud, compressing it.

Fossils content

Bioturbation is rare in this facies except for Outcrop 1(b) and Outcrop 2 with a moderate bioturbation index of 3 and 4. Most of the fossils found are trace fossils such as burrows, trails and tracks (Figure 4b).

2) F2: Laminated sandstone

Lithology and geometry

F2 is a common facies in the outcrops within the study area. It is light grey and grey in colour, with good to moderate grain size sorting. The grain sizes of laminated sandstone are mainly very fine to fine with silty or clayey lamination. Laminated sandstone beds (Figure 4c) range from 0.1 m to 0.5 m in thickness. The laminations of silt/mud are often thin with different configuration patterns for different beds including parallel, sub-parallel, irregular, chaotic and hummocky patterns. The beds have locally erosive or irregular upper and basal contact. The lateral continuity of the lamination within the sandstone varies.

Sedimentary structures

The main sedimentary structure in the F2 is the internal lamination siltstone/mudstone within sandstone beds. The horizontal stratifications differ showing patterns such as chaotic lamination, parallel lamination, wavy lamination and irregular lamination. Some of the beds show structure like climbing ripple lamination. Some lamination appears to be laterally continuous whereas some are pinching out. Mudclasts which are moderately well-rounded and spherical can be found in F2.

Fossils content

There is minor bioturbation in some of the laminated sandstone beds (index: 1 or 2). Most of the fossils found are trace fossils such as burrows, Skolithos (?) trace fossils and some traces from plants (?) (Figure 4d).

3) F3: Amalgamated sandstone

Lithology and geometry

Amalgamated sandstone is found at two of the upper beds in Outcrop 1(b). This facies is light grey-coloured as well as moderately sorted and graded in grain size. The grain sizes of F3 in the outcrop ranges from very fine to medium. They have a coarsening upwards sequence. The average thickness of the beds is around 0.4 m. The facies has an irregular upper and basal contact. There is thin siltstone /mudstone lamination within the upper amalgamated bed.

Sedimentary structures

The amalgamated sandstone beds lack in sedimentary structures. However, mudclasts can be found within the beds, often at the top part of the beds. Thin lamination of siltstone/mudstone can as well be observed. Presence of flame structure at the bottom of the bed may be resulted from the pressure of the overlying sandstone on the softer siltstone/mudstone.

Fossils content

Presence of fossils can hardly be observed from the beds. This facies has a minor bioturbation index of 1.

4) F4: Trough cross-bedded sandstone

Lithology and geometry

F4 can be found in Outcrop 2 and Outcrop 3. It is light grey to yellowish in colour, with good to moderate grain size sorting and grading. This facies has very fine grain sizes. The trough cross-bedded sandstone beds (Figure 4e) are lacking in lamination and stratification of other rock types. Outcrop 3 has a thin bed of F4 which is 0.1 m whereas Outcrop 2 has a thick bed of F4 which is 5 m. The beds have locally erosive or irregular upper and basal contact. F4 shows good lateral continuity across the outcrop.

Sedimentary structures

The main sedimentary structure in the F4 is trough cross stratification. The cross-bedding shows the deposition of sediments in different direction. Mudclasts can as well be found in F4.

Fossils content

F4 in Outcrop 2 has a minor bioturbation index of 2. Most of the fossils found are trace fossils such as burrows and some traces from plants.

5) F5: Interbedded siltstone/mudstone and sandstone (lenticular)

Lithology and geometry

F5 is common in the Outcrop 1(a), 1(b), 1(c) and Outcrop 2. The alternation of siltstone/mudstone and sandstone in F5 (Figure 4f) is light grey and grey in colour. The dominant rocky-type in the beds is siltstone or mudstone. Layers of very fine or fine-grained sandstone are deposited in between the silty or muddy facies. F5 has a thickness ranging from 0.03 m to 0.8 m. The thin sandy layers in between can be of a few centimeters. The beds have locally erosive or irregular upper and basal contact. The lateral continuity of the dominant siltstone/mudstone layers is good but the continuity of the sandy layers varies.

Sedimentary structures

F5 shows lenticular bedding where siltstone/mudstone is dominant in the beds. Most of the beds show planar or parallel stratification while some beds are irregular, wavy (Figure 4g) or sub-parallel. Flame structure can be observed when there is deposition of sand on top of the weaker silt/mud.

Fossils content

F5 is poorly to moderately bioturbated in some of the beds (index: 1 to 3). Most of the fossils found are trace fossils especially burrows.

6) F6: Heterolithic Siltstone/Mudstone

Lithology and geometry

F6 can be found in Outcrop 1(b) and Outcrop 2. Heterolithic siltstone/mudstone (Figure 4h) is the alternate deposition of siltstone/mudstone and sandstone but is mainly siltstone/mudstone dominated. It is light grey and grey in colour. The significant characteristic of heterolithic beds is that the each lamination of the sediments should be 1 mm or less in thickness. F6 has a thickness ranging from 0.1 m to 0.8 m. The beds have locally erosive or irregular upper and basal contact.

Sedimentary structures

F6 shows thin alternate stratification of siltstone/mudstone and sandstone where siltstone/mudstone is the dominant rocky-type within the beds. Most of the beds show planar/parallel stratification while some beds are irregular. Flame structure can be observed when there is deposition of sand on top of the weaker silt/mud.

Fossils content

Minor bioturbation is observed in F6 (index: 1) with rare observable fossils, probably due to weathering.

7) F7: Heterolithic Sandstone

Lithology and geometry

F8 is rare among the outcrops in the study area and can be found in Outcrop 1(b). Heterolithic sandstone is similar to F6 where the only difference is in terms of dominant rocky-type which is sandstone. It is light grey and grey in color. Each lamination of the sediments should be 1 mm or less in thickness. F6 has a thickness of 0.3 m. The beds have locally erosive or irregular upper and basal contact.

Sedimentary structures

F7 shows thin alternate stratification of sandstone and siltstone/mudstone where sandstone is the dominant rocky-type within the beds. The bed has parallel lamination. Flame structure can be observed when there is deposition of sand on top of the weaker silt/mud.

Fossils content

There are no observable fossils in F7 and no significant bioturbation.

DISCUSSION

Table 1 is the facies scheme of the study area. Observations from six measured sedimentary logs suggest that the study area consists of six facies associations (FA): (1) fluvial/channel facies, (2) middle estuarine facies, (3) subtidal to intertidal facies, (4) prodelta facies, and (5) storm deposits.

The cross-bedded sandstone facies is formed as migrating dunes from high energy unidirectional traction currents in fluvial channel sand bars. The unidirectional dipping or planar lamination suggests unidirectional and uniform currents. The relationshio of this facies with it under or overlying facies such as the heterolithic sandstone or mudstone (finer facies) and erosive basal contacts support this interpretation. There is a lack of trace or body fossils in within this facies in the study area, suggesting the deposition of the facie sin a freshwater environment.

The interbedded sandstone and mudstone/siltstone facies is formed from variable velocity, unidirectional traction current and suspension sedimentation. There is a relative constant flow direction and a constant sediment supply, with the absence of tidal indicators. This facies of mudstone/siltstone and sandstone is deposited in prodelta and delta front settings, respectively.

The heterolithic mudstone facies is interpreted as deposits from alternating flood-ebb tidal currents and intervening slackwater suspension fallout in the lower tidal flat or subtidal coastline settings. Mud couplets or drapes, lamination bundles and thickness variations are some of the criteria that infer the occurrence of tidal process. The process may also be associated with sigmoidal cross-stratification in the facies.

The heterolithic sandstone is deposited in upper tidal flat, tidal channel or upper subtidal coastline settings which

Table 1: Facies scheme of the study area.

Lithofacies	Process	Environment
Laminated sandstone	Upper flow regime plan bed migration (varying energy).	Middle estuarine tidal
Laminated mudstone to siltstone/VF sandstone	Suspension fallout (low energy).	Restricted estuarine basin or embayment, restricted offshore transition
Cross-bedded sandstone, fine-grained sandstone	High energy, unidirectional traction sedmentation.	Fluvial channel sand bar
Interbedded sandstone and mudstone/siltstone	Unidirectional traction and suspension sedmentation (varying energy).	Non-tidal prodelta, delta front
Heterolithic mudstone	Lower energy tidal currents and slackwater fallout.	Lower tidal flat or subtidal coastline
Heterolithic sandstone	High energy tidal current and slackwater fallout.	Upper tidal flat, channel or coastline (subtidal-intertidal)
Bioturbated sandstone	Transgressive biologic and storm current sediment reworking.	Transgressive lag, storm deposits

is a subtidal to intertidal environment. The deposition is due to high energy tidal current and intervening slackwater fallout. Several exclusive features which can be observed are mud couplets/drapes with flaser or lenticular laminae and reactivation surfaces (indicating fluctuating flow velocities).

Last but not least, the bioturbated sandstone facies found in some sandstone beds is interpreted as transgressive lag or storm deposit. There is a high energy current deposition due to marine flooding or storm currents that was subsequently bioturbated. Comparison with the under or overlying facies such as heterolithic sandstone/ mudstone or interbedded sandstone/mudstone supports the interpretation. The facies is overlain by finer grained facies. This suggests a period of higher energy current deposition due to marine flooding or storm reworking.

The Tatau Formation is characterized by sand-dominated facies as well as mixed-sand and mud-dominated facies. The facies strata are interpreted as estuarine, tidal flat, fuvial deposition and up to inner shelf strata. The laboratory analyses which suggest the presence of arenites signify the erosion of rocks or turbiditic re-deposition of sand which is probably originated from higher and inner ground. The deposition of arenites is then associated with deposition of lutite which is finer-grained sediments such as siltstone and mudstone which its source may come from inner ground or further erosion of sediments during transportation. There is a change and fluctuation in energy within the depositional environment due to frequent facies change and their structures.

Besides, the presence of trace fossils in the study area suggests that during the period of deposition, there was adequate and sufficient accommodation space and food supply within the environment of deposition until the deposition phase ends. The living organisms were able to accommodate themselves for a certain period of them with sufficient nutrient supply. Therefore, the evident supports the deduction of an estuarine-inner shelf region which belongs to the shallow marine environment.

CONCLUSION

The Tatau-Bintulu area has been categorized as part of the Miri Zone of Sarawak Basin. For early Neogene formations of the study area, focus of this study is on the sedimentary formations that overlie the Belaga Formation (Paleogene). Tatau Formation is geologically and stratigraphically related to the study area.

The Tatau Formation consists mainly of carbonaceous shale and siltstone, with some beds of sandstone. Although there is no observable unconformity, photogeological and field evidence suggested that the Tatau Formation lies unconformably on the Belaga Formation.

From the field study as well as laboratory analysis, the outcrops in the study area do show similar facies and characteristics as the Tatau Formation. The common rock types present are sandstone, mudstone and some rare shale. Seven types of facies which can be categorized into sand-dominated facies or mixed sand and mud-dominated facies were identified. Fluctuation in depositional energy resulted in alternation of sediments and their structures from finer to coarser sediment and planar to erosive surfaces. The rise and drop in sea level influence the energy during the deposition phase as well as sequence of deposition (fining-upward or coarsening-upward sequence). Besides, the available accommodation space influences the thickness of the sediments deposited from thinner beds to thicker beds. The facies associations in the study area propose an estuarine-inner shelf environment, showing rare transgressive characteristics.

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Predicting uniaxial compressive strength using Support Vector Machine algorithm

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Abstract: Compressive strength is the most important parameter in rock since all loads will be transferred and rest on the rock which is based on the load bearing capacity of rock in compression. However, obtaining the compressive strength or mostly measured, the uniaxial compressive strength (UCS) from the laboratory test requires certain standard and also cost constrain. This paper presents the application of Support Vector Machine (SVM) algorithm to predict the UCS. An algorithm has been tested on a series of rock data using dry density and velocity parameters. The relationship between the dry density, sonic velocity, and UCS was analyzed using RapidMiner Studio software. From the result, it was found that SVM is capable of predicting the missing values with a prediction trend accuracy of 75%. The results obtained and observation made in this study suggests that SVM could be a reliable tool to predict the UCS of a given rock. More robust prediction can be established with bigger sample number. It is worth mentioning, that the program module that has been set up could be used repeatedly for other correlation problems.

Keywords: unconfined compressive strength, dry density, sonic wave velocity, support vector machine

INTRODUCTION

Rock mechanics is an essential part of geotechnical engineering. One of the most important parameters of rocks is the uniaxial compressive strength of the rock sample. However, obtaining sufficient core sample with the proper quality for direct testing is often hindered especially in weathered or/and fractured rocks. Most commonly used correlation is using the sonic wave velocity logging, which is an indirect test. The correlation established by McNally, 1990 states that, UCS:

$$UCS = 1000 \times e^{-0.035t} \quad \text{(Equation 1)}$$

where the UCS is in MPa and t is the sonic travel time in microsecond/feet.

However, some researchers have suggested that this equation does not take into account the variations due to rock mass parameters (Hatherly *et al.*, 2009; Medhurst *et al.*, 2010; Barton, 2006). Other researchers suggested that the correlation of UCS and sonic velocity should be done on a regional basis, and they also believe that a linear relationship is the most appropriate for this relationship (Sharma & Singh, 2008).

In establishing the correlation, firstly, the regression analysis techniques are often used to predict unavailable data. This technique has a major flaw, of which it only predicts the mean value of the data. This may lead to inaccurate prediction, especially in non-linear equation problems. This flaw may be countered using supervised machine learning algorithm; machine learning is part of computer science, developed from the study of pattern recognition and computational learning theory in Artificial Intelligence. Machine learning explores the study and construction of algorithms that can learn from and make predictions on data. Commonly known machine learning is Artificial Neural Networks (ANN). Regardless, the ANN does not force the predicted data to be a mean value, thus preserving and using the existing variance of the measured data.

This limitation has been resolved using the SVM. Therefore, this study aims to predict missing UCS values using sonic wave velocity and dry density parameters by utilizing the SVM.

LITERATURE REVIEW

Support vector algorithm is a nonlinear generalization of the *Generalized Portrait* algorithm developed in Russia in the sixties (Vapnik & Lerner, 1963; Vapnik & Chervonenkis, 1964). It is a supervised learning model with associated learning algorithms that analyze data and recognize patterns, used for classification and regression analysis. In regression and time series prediction applications, excellent performances were reported using SVM (Muller *et al.*, 1997; Drucker *et al.*, 1997; Stitson *et al.*, 1999; Mattera & Haykin, 1999). Just recently, SVM has come into attention for solving the engineering problem, in which SVM characterizes properties of learning machines which enable them to generalize well to unseen data.

SVMs can be used to solve in many real life problem such as 1) classification of images, 2) hand-written characters recognition and 3) predictions.

EXPERIMENTAL SETUP

In establishing the results, the experiment is divided into data preparation phase, which is described in later section.

Data preparation

In this study, a total of 160 data, of which 140 data is regarded as complete (ie: have both UCS and sonic wave velocity values) of which are used to learn, and 20 data that are incomplete has been gathered from the Jabatan Kerja Raya (JKR). The data is then analyzed and cleansed to get rid of unwanted attributes such as the site location, borehole number, sample number, etc. The attribute chosen to be analyzed is trimmed and copied into another file. Two files were created through this process. One of the file consists of complete data set (UCS, sonic velocity and dry density), whilst the other file consists of data set with missing UCS values. The first file (learning data set) is important to train the SVM algorithm the existing correlation values between the attributes so that it can be applied and predicted the missing values in the second file (prediction data set). The data is then imported into the Rapid Miner Studio software, of which shall be explained in the following sections.

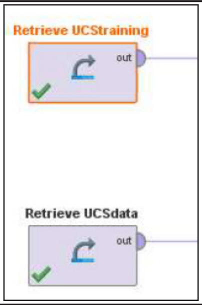
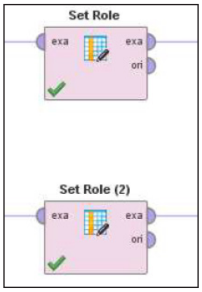
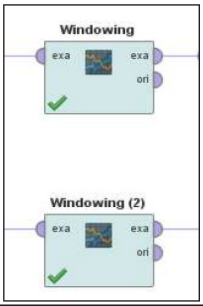
Programming the module

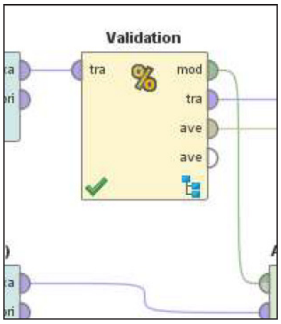
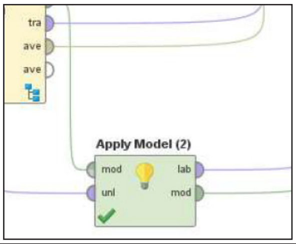
Rapid Miner software comes with a user-friendly graphical user interface (GUI). However, to use the software effectively, the function and limitation of each operator must be understood before it can be utilized. Each of the operators will be explained in details in the Table 1.

RESULTS AND DISCUSSION

Once the analysis is completed, the RapidMiner software; thru the Forecasting Performance operator, gave a prediction trend accuracy of 75%, which is accurate enough considering that there are not enough data as compared to a major research involving thousands of data. Figure 1 shows almost identical trend between the actual UCS versus the predicted UCS values shown almost identical trend, in which reflects to the good agreement found between these values.

Table 1: SVM operating module.

Operator	Screenshot
Retrieve operator This operator reads an object from the data repository. It is more efficient to use this operator since it provides full meta data processing, which eases the usage of RapidMiner a lot. In contrast to accessing a raw file, it provides the complete meta data of the data set, so all meta data transformations are possible.	
Set Role operator This operator is used to change the role of one or more attributes. Changing the role of an attribute may change the part played by that attribute in a process. Different learning operators require attributes with different roles. This operator is used to set the right roles for attributes before applying the desired operator. At this stage, the UCS attribute are set to the "label" role as it acts as a target attribute for learning operators (e.g. SVM, Decision Tree, etc.).At the bottom Set Role operator, the UCS attribute is set to a prediction role, as it will act as a predicted attribute of a learning scheme.	
Windowing operator This operator transforms a given example set containing series data into a new example set containing single valued examples. For this purpose, windows with a specified window and step size are moved across the series and the attribute value lying horizon values after the window end is used as label which should be predicted.	

X-Validation operator This operator performs a cross-validation in order to estimate the statistical performance of a learning operator. It is mainly used to estimate how accurately a model will perform in practice. There are two sub-processes in this operator: a training subprocess and a testing subprocess. The training subprocess is used for training a model. The trained model is then applied in the testing subprocess. The performance of the model is also measured during the testing phase.	
SVM operator Nested inside the X-Validation operator, at the training subprocess, is the SVM (Support Vector Machine) Learner operator. This learning method can be used for both regression and classification and provides a fast algorithm and good results for many learning tasks. This operator supports various kernel types including *dot, radial, polynomial, neural, anova, epachnenikov, Gaussian combination* and *multiquadric*. The standard SVM takes a set of input data and predicts, for each given input, which of the two possible classes comprises the input, making the SVM a non-probabilistic binary linear classifier. Given a set of training examples, each marked as belonging to one of two categories, an SVM training algorithm builds a model that assigns new examples into one category or the other. An SVM model is representation of the examples as points in space, mapped so that the examples of the separate categories are divided by a clear gap that is as wide as possible. New examples are then mapped into that same space and predicted to belong to a category based on which side of the gap they fall on.	
Apply Model operator This operator applies an already learnt or trained model on a dataset. After the model is trained using learning operators (eg: SVM, Decision Tree, etc.), the model can be applied on another data set; usually for prediction purposes. All needed parameters are stored within the model object. It is compulsory that both data sets have exactly the same number, order, type and role of attributes. If these properties of meta data are not consistent, it may lead to serious errors.	
Forecasting Performance operator This operator delivers as output a list of performance values according to a list of selected performance criteria for forecasting regression tasks.	

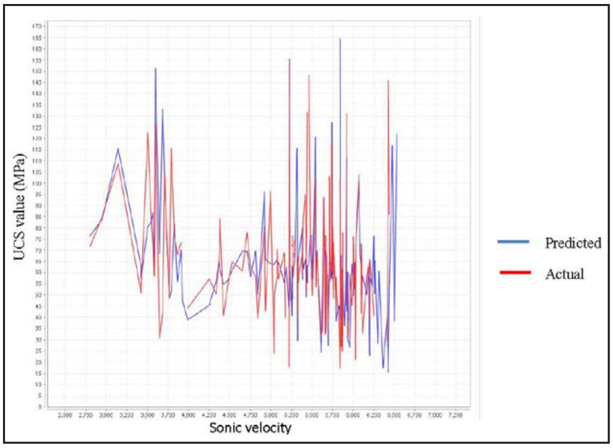


Figure 1: UCS (predicted and actual) versus sonic velocity.

A comparison has been made with the actual, predicted and UCS value that have been obtained using McNally's equation (Equation 1). Figure 2 indicates that the predicted UCS values are closer to the actual UCS values compared

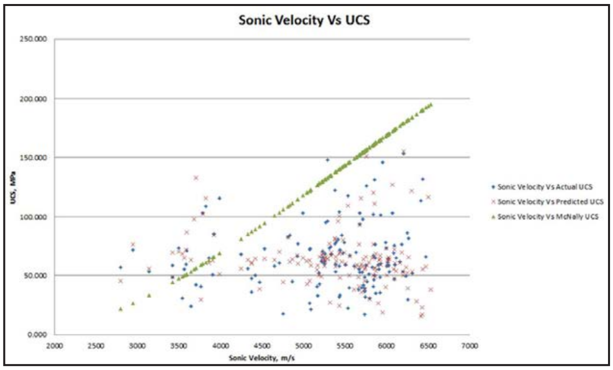


Figure 2: UCS versus sonic velocity.

to the UCS values generated by the McNally's equation. This confirmed that the predicted data will yield a more accurate result as compared to the existing equation.

It should be highlighted that, this situation can be very helpful in cases of projects that rely on small existing data to predict any missing values that are encountered.

CONCLUSIONS

The results obtained and the observation made in this study draw some conclusions. Support Vector Machine algorithm has been successfully utilized to predict the UCS value with 75% accuracy. A more robust prediction can be achieved with bigger number of data set. It is worth mentioning that, the programmed module that was generated can be used to predict any missing data that has an established correlation. This could make future prediction easier and faster. Most importantly, there are still many application of SVM that can and must be explored to solve the engineering difficulties.

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Revised manuscript received 7 January 2019
Manuscript accepted 28 February 2019

A Malaysian geologist in New York[1]

BY [2]MAZLAN MADON

The author at the entrance of the United Nations Headquarters in New York, where it is usually crowded with tourists. Photo was taken in 2015 on Hari Raya Aidilfitri, which is also an official UN holiday. In the background is the UN Secretariat Building where the General Assembly is held.

The work of a geologist might be perceived by some people as "unglamorous" because it deals with "earth", "soil", "rocks" and "stones" which, to the uninitiated, could be described simply as "dirt". Some geologists have to climb steep mountains or work hundreds of miles offshore in turbulent seas, so it would be fair to think that a geologist's job is "difficult, dirty and dangerous" – the dreaded '3-D' which existed well before today's young graduates were even born! Among the many types of geologists, a "research geologist" (picture a geologist in a lab coat) would rank even lower on the "glamour" scale.

But I have no regrets. Having worked for over 30 years with Petronas, little did I know that I was actually preparing myself for a more important task, as a Malaysian scientist, to serve as member of a UN body of technical experts on the delineation of the outer limits of the continental shelf, as provided for under the United Nations Convention on the Law of the Sea (UNCLOS) 1982.

So, what is UNCLOS, and what is its relevance to the continental shelf?

The UNCLOS is sometimes regarded as the "constitution of the oceans. It contains the rules in which the international community has agreed to abide by in dealing with matters on ocean governance. Such matters include rules on navigation, resource development, the protection and preservation of the marine environment, and the definitions of maritime spaces such as the exclusive economic zones and the continental shelf.

Article 76 of the UNCLOS defines the continental shelf of a coastal State as "*the seabed and subsoil of the submarine areas that extend beyond its territorial sea throughout the natural prolongation of its land territory to the outer edge of the continental margin, or to a distance of 200 nautical miles from the baselines from which the breadth of the territorial sea is measured where the outer edge of the continental margin does not extend up to that distance*".

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1 This is a modified version of an article that first appeared on Astroawani website on 19 January 2019. The views expressed in this article are solely of the author's and do not necessarily reflect the views of the Commission on the Limits of the Continental Shelf.

2 Dr Mazlan Madon is a fellow of the Academy of Sciences Malaysia and Immediate-Past President of the Geological Society of Malaysia. With his vast experience in petroleum exploration and marine geology, and as a member of CLCS since 2012, he also serves as Advisor to Malaysia's Continental Shelf Project, which is tasked to prepare Malaysia's claims on its extended continental shelf for submission to the CLCS.

An early photo, circa 1986, of the author in a lab coat (sitting on the right), looking at core samples through a microscope in the dusty core warehouse in Ulu Kelang, where the Petronas laboratories used to be located but now is the site of the Petronas Geoscience Sample Centre.

In essence, article 76 provides the formulae by which a coastal State is able to define its continental shelf by establishing its outer limits. In simple terms, a coastal State may delineate the outer limits of its continental shelf based on geological and hydrographic information that its continental margin extends beyond 200 nautical miles from the coast.

In order to facilitate this process, a body of experts called the Commission on the Limits of the Continental Shelf (CLCS) was established in 1997 under the UNCLOS for the purpose of making recommendations on the outer limits of the continental shelf of submitting coastal States. Under article 76 of UNCLOS, a coastal State may submit to the CLCS particulars (including geological and scientific information) relating to the limits of the continental shelf beyond 200 nautical miles. The main role of the CLCS is therefore to examine the geological and hydrographic data and information submitted by coastal States to justify their extended continental shelf beyond 200 nautical miles (Figure 1). UNCLOS requires that 21 experts in geology, geophysics or hydrography, be elected from among the nationals of the coastal States every 5 years to serve, in their personal capacities, as a member of the CLCS. As an independent body, the CLCS examines the scientific and technical data and information pertinent to a coastal State's continental margins. Article 76 of UNCLOS makes use of geological concepts, such as "continental shelf" and "continental margin", and thus, geology plays an important role in the work of the CLCS. This is a rare but critical role in which geology (and the geologist) plays in the international arena.

The CLCS conducts its work at the UN headquarters in New York for a total of 21 weeks per year. The work is organized in three (3) sessions per year, with each session lasting for seven (7) consecutive weeks. Despite this long schedule, it still has a big task to complete its work and try to keep up with the increasing number of submissions by coastal States. Due to the enormous political and economic implications, coastal States have been submitting information on their extended continental shelves to the CLCS since 2001, and in some regions around the world, this has resulted in overlapping territorial claims by coastal States. The work of the CLCS is a way of addressing this issue among neighbouring coastal States in a peaceful manner.

The delineation of maritime spaces has important implications on the rights of coastal States to explore and exploit natural resources of the seabed in marine areas beyond their national jurisdiction (200 nautical miles from shore). The rights of the coastal State over its continental shelf is stipulated in Article 76 of UNCLOS, primarily in that the coastal States exercise sovereign rights over the continental shelf for the purpose of exploring it and exploiting its natural resources. "Natural resources" here includes mineral, oil, gas and other non-living resources on the seabed and subsoil, as well as living organisms belonging to sedentary (benthic) species.

Due to its high importance, Malaysia has been contributing significantly to the work of the CLCS since its inception in 1997, by nominating its own experts to serve in that body. As the work of the CLCS deals with the marine environment, I am glad that my own research experiences in marine geology and offshore petroleum exploration have prepared me well for the role. My predecessor in the CLCS was Dato' Dr. Abu Bakar Jaafar, FASc., who served the CLCS for three terms from 1997 to 2012. In 2012, I was elected to my first term, while still working with Petronas, and in 2017 to the second term, just after my retirement from the petroleum industry.

Besides serving in the CLCS, I also serve as Advisor to the Malaysian Continental Shelf Project which is under the direction of the Majlis Keselamatan Negara, Jabatan Perdana Menteri. The project team, comprising technical and legal experts, is charged with preparing Malaysia's submission of its continental shelf claims to the CLCS. In 2009, Malaysia submitted to the CLCS, a joint submission with Vietnam, the particulars regarding its claim to areas beyond 200 nautical miles in the South China Sea, and is awaiting them to be considered by the CLCS.

At the time of writing this article, the CLCS has received altogether 81 submissions and 7 partial revised submissions from coastal States (a total of 88). Depending on various factors, among which are the complexity of the geology and the technical aspects of the submissions, it may take the CLCS between several months to more than five years to examine a submission. To date, 42 submissions have been examined by the CLCS since 2001 but only 29 recommendations have been made. Hence, there is still a long way to go before the work of the CLCS is complete. It is therefore crucial that the work of the CLCS continues to receive support, including financial, from the States which are parties to the UNCLOS so that it can carry out its mandate provided under the convention.

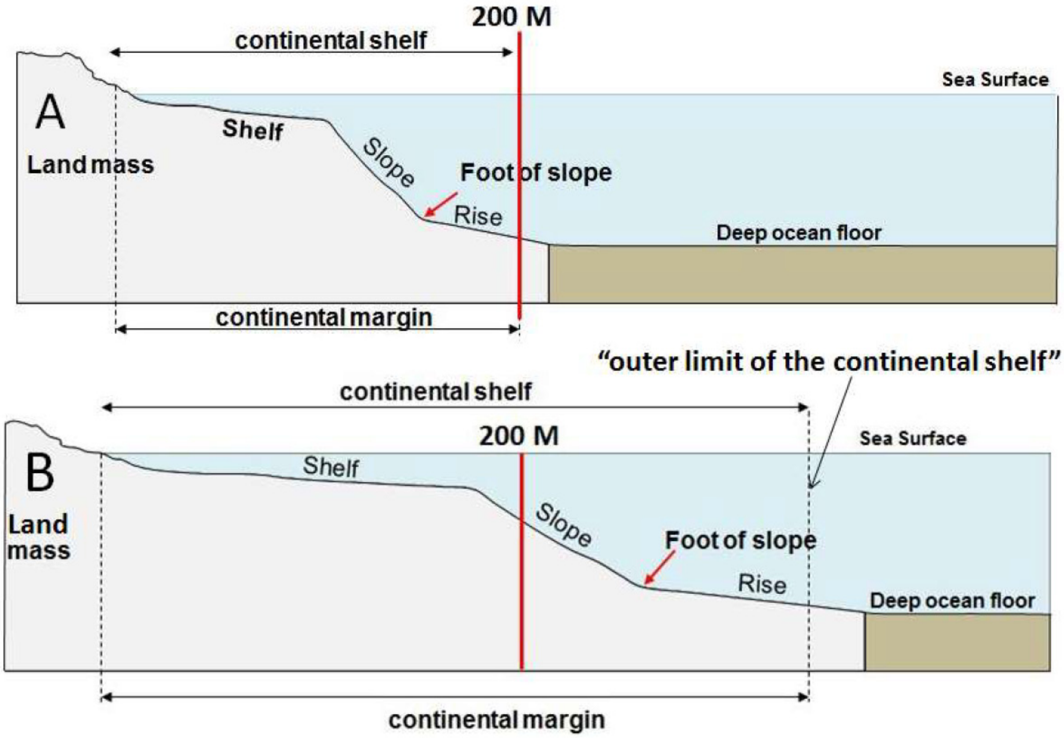

Figure 1: Legal concept of the "continental shelf" in relation to the geological continental margin (shelf, slope and rise) under the UNCLOS. (A) a narrow continental margin less than 200 nautical miles (M) wide would entitle the coastal State a "continental shelf" equals to 200 M (or equivalent to the Exclusive Economic Zone). (B) a wide continental margin that extends beyond 200 M would entitle the coastal State that part of the continental margin beyond 200 M, up to a defined limit. The "outer limit of the continental shelf", in such a case, is defined according to article 76 of UNCLOS, upon recommendations by the Commission on the Limits of the Continental Shelf (CLCS). Modified figure from "The Law of the Sea: Training Manual for Delineation of the Outer Limits of the Continental Shelf", United Nations, Division of Ocean Affairs and the Law of the Sea, 2007.

CERAMAH TEKNIK TECHNICAL TALK

Petrologi dan geokimia batuan volkanik di Blok Timur Malaya, Semenanjung Malaysia

Muhammad Hatta Roselee
Date: 13 March 2019
Venue: Bilik Mesyuarat, Program Geologi, Universiti Kebangsaan Malaysia

Sinopsis: Kajian terhadap batuan volkanik di Blok Timur Malaya di Semenanjung Malaysia secara langsung akan menyumbang terhadap penentuan proses evolusi dan petrogensis magma serta subduksi tektonik kerak lautan Palaeo-Tethys ke bawah kerak benua Indochina. Blok Timur Malaya terdiri daripada gabungan Jalur Timur dan Jalur Tengah di Semenanjung Malaysia, di mana kedua-dua jalur ini termasuk dalam kajian ini. Kedua-dua aliran lava dan piroklastik boleh dijumpai di Blok Timur Malaya yang didominasi oleh batuan igneus tipe-I. Batuan volkanik boleh dibahagikan kepada kumpulan felsik, pertengahan dan mafik mengikut komposisi kandungan geokimia. Batu volkanik felsik kebanyakannya terdiri daripada komposisi riolitik hingga riodasitik. Batuan volkanik pertengahan pula terdiri daripada andesitik hingga dasitik manakala batuan volkanik mafik daripada basaltik-andesit kepada basaltik berdasarkan klasifikasi geokimia serta pemerhatian petrografi. Terdapat sebilangan kecil batuan volkanik dari kuari Sg. Jan dan Pulau Tenggol yang menunjukkan perkaitan dengan '*syn to post collisional slab-break off extension*'. Batu volkanik berkomposisi felsik, pertengahan dan mafik dicirikan oleh nilai Al_2O_3 yang tinggi dengan nilai purata sebanyak 15.5%, 16.2% dan 16.8% masing-masing dan bersifat metaluminus kuat ke peraluminous lemah. Selain itu, batuan volkanik juga menunjukkan nilai yang rendah bagi MgO (<10%), nombor Mg# (<60), Ni dan Cr di mana ciri-ciri ini menunjukkan sumber magma yang membentuk volkanik ini adalah tidak primitif. Corak geokimia dalam gambarajah spider bagi unsur pelbagai dan unsur nadir bumi menunjukkan persamaan antara batuan volcanik felsik, pertengahan dan mafik mencadangkan batuan volkanik tersebut mungkin berasal dari sumber yang sama. Dicadangkan bahawa proses magmatik lebih dipengaruhi oleh fraksinasi mineral seperti olivin, klinopiroksen dan hornblen dalam mafic magma yang akhirnya membentuk batuan volkanik yang mengadungi Al_2O_3 yang tinggi tetapi mempunyai kandungan MgO, Ni dan Cr yang rendah. Kontaminasi kerak tidak penting untuk batuan volkanik mafik dan pertengahan tetapi memainkan peranan penting dalam batuan voklanik felsik. Teknik pengusiaan U-Pb zircon ke atas batuan volkanik menunjukkan usia berjulat daripada 279 juta tahun ke 213 juta tahun (Perm Awal hingga Trias Lewat). Nilai-nilai eHf dari batuan volkanik dengan sokongan diskriminasi tektonik geokimia dan geokronologi menunjukkan bahawa subduksi kerak lautan Palaeo-Tethys ke bawah Blok Timur Malaya-Sukhothai telah berterusan dari Perm Awal hingga Trias Lewat (279 Ma hingga 225 Ma) sehingga subduksi terhenti di sebabkan oleh perlanggaran orogeni Indosinia (perlanggaran Sibumasu- Indochina) kira-kira dalam lingkungan 220 juta tahun hingga 210 juta tahun. Perlanggaran ini kemudian diikuti oleh patahan kerak semasa ~213 juta tahun. Magmatisma di Blok Timur Malaya boleh dikaitkan dengan arka Sukhothai di Thailand (utara) dan Singapura (selatan) berdasarkan perbandingan data geokronologi, isotop dan geokimia dengan kajian yang telah diterbitkan sebelum ini.

CERAMAH TEKNIK TECHNICAL TALK

Introduction to modern methods of geophysical site investigations

Muhammad Mustaqim Mohd Rosli (ABEM / MALA)
Date: 27 March 2019 (Wednesday)
Venue: Bilik Mesyuarat Program Geologi, Bangunan Geologi, FST, Universiti Kebangsaan Malaysia, Bangi

SYNOPSIS: A very precise understanding of what the resistivity, seismic and electromagnetic methods used in geophysical exploration, is what this presentation out to explain. More important is the fact that all methods maybe used to complement each other for a better understanding of the subsurface of the Earth in -terms of structures, having a form of electrical property, elasticity, which may be present. Geophysical techniques are the various physical methods which are used in geophysical exploration. They are also referred to as geophysical survey methods. Geophysical exploration involves the applications of the principles of geophysics to geological exploration. Geophysical methods can be classified in various ways. In terms of their source of energy, they can be classified as active methods or passive methods. Active methods are those which require the input into the earth of artificially generated energy or artificial signal and the Earth's response to the signal is measured. Some methods involve the generation of local electrical or electromagnetic fields that may be applied analogously to natural fields. Examples of active geophysical methods are seismic, electrical resistivity, electromagnetic methods, ground-penetrating radar, and induced polarization. In this presentation, the resistivity will be the main focus since it is the most robust method and steps to acquire better data with more efficient within the modern instrument.

Thought-provoking observation of the SEA World Gravity Map

Zuhar Zahir Tuan Harith
Date: 27 March 2019 (Wednesday)
Venue: Bilik Mesyuarat Program Geologi, Bangunan Geologi, FST, Universiti Kebangsaan Malaysia, Bangi

Dr. Zuhar Zahir Tuan Harith (PGeo) has approximately 20 years of experience in all aspects of the planning, management, and implementation of geophysical investigations, including, survey design, cost estimates and proposals, data acquisition and interpretation, preparation of reports and scientific publications, and professional teaching and training.

SYNOPSIS: The World Gravity Map (WGM) represents a set of high-resolution gravity anomaly maps and digital grids computed at global scale from available reference Earth's gravity and elevation models. The gravity anomaly is defined as the difference between gravitational acceleration caused by the earth's masses and that generated by a reference mass distribution. In geophysics, the gravity anomalies are used to investigate the mass-distribution of the Earth interior to provide constrains on the geological structures from subsurface, crustal to upper mantle depths. This presentation present some of the interesting observation of WGM in the region of SEA with special emphasize in Peninsular Malaysia and Malay Basin. Thought-provoking observation on various geological aspect / concept such as hot-spring distribution, active fault / earthquake and many more will be presented. These out-of–the box observations are hopefully will trigger some new way of looking at geology of Malaysia.

Session with Unit Sokongan Penyelidikan, UM

On 25 March 2019, the Editorial Group members who had gathered for a meeting were fortunate to have two invited guests, Puan Mona Simarani and En. Mohd. Salleh Sa'ari, from Unit Sokongan Penyelidikan, Universiti Malaya.

Started at about 11.00 a.m., the first speaker was Puan Mona, who gave a presentation on 'Open Journal System' i.e. a software for management and publishing of peer-reviewed academic journals. Using examples from journals that are already users of this platform, Puan Mona presented the operations involved in the OJS, that includes the online submission and management of manuscripts processes, distribution of manuscript copies, assigning manuscripts to section editors or reviewers, reminding reviewers of due dates, etc. The presentation was enlightening and demonstrated that by adopting the system, the amount of time and effort to deal with clerical tasks can be much reduced.

The presentation by Puan Mona was followed by a dialogue session with En. Mohd. Salleh on matters pertaining to the application for indexing of the Bulletin by the Web of Science (WOS). As the Bulletin had already been recently submitted for evaluation, the scheduled presentation on 'Kriteria Perindeksan Jurnal Di Web of Science dan Scopus' was replaced with a Q&A session. A check on the online bulletin was made by En. Mohd. Salleh prior to the meeting and according to him, the Bulletin has fulfilled most of the requirements for the indexing. A few improvements were then suggested. The standard procedure and timeframe for the evaluation process were also highlighted.

The second session ended at 1.00 p.m., and before the departure of the two speakers, a token of appreciation was presented to them each by Prof. Wan Hasiah.

Acknowledgement of Peer Reviewers for 2018

In appreciation of the enormous contribution they make to the Society's publications, we would like to thank the scholars and experts below who have participated in the peer review process of manuscripts submitted for consideration for publication in the Bulletin of the Geological Society of Malaysia and Warta Geologi in 2018:

1. Ahmad Farid Abu Bakar
2. Allan Filipov
3. Askury Abd. Kadir
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5. Che Aziz Ali
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7. Clare Barker-White
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39. Samie Lee
40. Selvarajah Marimuthu
41. Shirin Fassihi
42. Tan Boon Hua
43. Tan Boon Kong
44. Tee Ai Teng
45. Titus Murray
46. Zuhar Zahir Tuan Harith

Notice of 53rd Annual General Meeting

PERSATUAN GEOLOGI MALAYSIA
GEOLOGICAL SOCIETY OF MALAYSIA
c/o Department of Geology, University of Malaya, 50603 Kuala Lumpur, Malaysia
Tel: 603 – 7957 7036 Fax: 603 – 7956 3900 email: geologicalsociety@gmail.com

To all GSM Members

NOTICE OF 53rd ANNUAL GENERAL MEETING

In accordance with Article VII of the Constitution, notice is hereby given that the 53rd Annual General Meeting of the Geological Society of Malaysia will be held:

on **Monday, 29 April 2019 at 2.30 pm.** Registration is between 2:00 pm to 2:30 pm.

at **Persatuan Alumni Universiti Malaya (PAUM) Club House**
Jalan Susur Damansara (Jalan Damansara Lama), Off Jalan Gegambir, Kuala Lumpur
| Tel: 03-2093 1235 | http://umalumni.my/

The Agenda for the Annual General Meeting is as follows:

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
    - President's Report
    - Secretary's Report
    - Editor's Report
    - Treasurer's Report
    - Honorary Auditor's Report
    - GSM Endowment Fund Report
5. Election of Honorary Auditor
6. **Other Matters**
   Of which **Written Notice** is submitted to reach GSM Secretariat by the 21st April 2019, or by majority vote of the AGM
7. Announcement of New Council for 2019/2020
8. Presidential Address for 2019/2020

Please note that no **Other Matters** shall be discussed, unless prior written notice is received by the **21st April 2019** (at least 7 days before the meeting) or by majority vote of the Annual General Meeting. This is in accordance with the Article VII, Section 4 of the Constitution.

Thank you.

Yours faithfully,
GEOLOGICAL SOCIETY OF MALAYSIA

Lim Choun Sian
Secretary 2018/2019
11 March 2019

NEW MEMBERSHIP

Full Membership

1. Abdul Hakim Yahaya
2. Ahmad Nazmi Mohd Noor Azudin
3. Farah Fazulah Abdullah
4. Hisam Hj Ahmad
5. Mohd Shafiq Farhan Mohd Zainudin
6. Muhammad Aiman Abdul Aziz
7. Muhammad Nurul Firasat Mohd Yusuf
8. Norazianti Asmari
9. Nur Farhana Md Izham
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2. Mohd Zain Ghazali
3. Wael Ben Habel

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27. Mohamad Muzakkir Mustaffa
28. Mohd Fikhri Abdullah
29. Mohd Hafsham Wahaf
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39. Nor Intan Shazlin Mohamad Rojali
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NGC 2019

"Geosciences for the Earth Sustainability"

UMS UNIVERSITI MALAYSIA SABAH

NATIONAL GEOSCIENCE CONFERENCE 2019 (NGC 2019)

1st - 3rd October 2019
The Palace Hotel,
Kota Kinabalu, Sabah

1ST ANNOUNCEMENT

The Geological Society of Malaysia is pleased to announce that the National Geoscience Conference 2019 (NGC 2019), 32nd in the annual conference series, will be held in Kota Kinabalu, Sabah from 1st to 3rd October, 2019. The Conference is a premier geoscientific event in Malaysia and the region, which is well attended by geoscientists from academia as well as the public and private sectors. NGC 2019 is co-organised with the Faculty of Science and Natural Sciences, Universiti Malaysia Sabah and the Mineral and Geoscience Department Malaysia (JMG).

PROGRAMME

The technical program of NGC 2019 consist of oral and poster presentations on all aspects of geoscience, Environment and technology related to the theme. Presentation will be delivered by keynote speakers on topics of relevance to the theme and interest to the nation. There will be a one-day post-NGC 2019 Fieldtrip to Kundasang, Ranau, Sabah.

All papers accepted will be published in the special issues of Bulletin of Geological Society of Malaysia or Index by Scopus

THEME:
Geosciences for the Earth Sustainability

As we move forward through the modern era, the practice of science and technology is omnipresent. Knowledge of the earth's system and processes, together with the application of technology has improved our quality of life through the utilisation and management of the earth's natural resources such as rocks, minerals, petroleum, natural gas and groundwater.

SCOPE

- Disaster Risk Reduction, Engineering Geology & Rock Mechanics
- Mining & Quarry
- Tectonic & Structural Geology
- Petroleum Geology, Sedimentology & Paleontology
- Hydrogeology, Environmental Geology & Geochemistry
- Conservation Geology, Geoarcheology, & Geotourism
- Any related to the applied or techniques in Geosciences

REGISTRATION FEE

Registration Type		Conference		Workshop	Fieldtrip
		Early Bird	Normal Fee		
		MYR	MYR	MYR	MYR
Presenters GSM members		500	550	100	80
Presenters Non-Member		550	600		
Student	Members	400	450		
	Non-member	500	550		

IMPORTANT DATES

30th June 2019	: Submission of Extended Abstract
30th July 2019	: Notice of Abstract Acceptance
31st August 2019	: Early Payment
15th September 2019	: Normal Payment
30th September 2019	: Workshop (Importance of Geoscience on Sustainable Development)
1st October 2019	: Workshop (Disaster Risk Reduction DRR)
1st - 2nd October 2019	: Conference
3rd October 2019	: Fieldwork (Kundasang)
30th November 2019	: Full Paper Submission

WORKSHOP

A total of two series of workshop will be held:

1. Importance of Geoscience on Sustainable Development (30/09/19); and
2. Disaster Risk Reduction (DDR) (01/10/19).

Details will be announced in the next circular.

FIELDTRIP

A post-conference fieldtrip to the best place to visit in Sabah (Kundasang). Detail will be announced in the next circular.

No	Hotel	Contact number
1	The Palace Hotel, Kota Kinabalu (NGC 2019 Conference Venue)	088217222
2	Hilton Hotel, Kota Kinabalu	088356000
3	Cititel Express Hotel, Kota Kinabalu	088521188
4	Promenade Hotel, Kota Kinabalu	088265555
5	The Klagan Hotel, Kota Kinabalu	088488908
6	Le Meridian Hotel, Kota Kinabalu	088322222
7	Marina Court, Kota Kinabalu	0163311175
8	Tang Dynasty Hotel, Kota Kinabalu	088263389
9	Sky Hotel, Kota Kinabalu,	01548761941
10	Oceania Hotel, Kota Kinabalu	088255818

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Dr. Asmahani Awang: 088-320000 ext. 5584

AGSCE – Empowering Future Geoscientists

Asia Geoscience Student Conference & Exhibition (AGSCE) 2018, a monumental milestone, hosted by Universiti Teknologi PETRONAS (UTP), was a 2-day international event held from 29th October to 30th October 2018. To empower the geoscience student community in Asia, EAGE UTP and AAPG UTP Student Chapters worked in tandem to organise the first edition of AGSCE, which was participated by over 400 attendees from 6 countries, 16 different universities from Asia as well the endorsement of 17 sponsors and exhibitors.

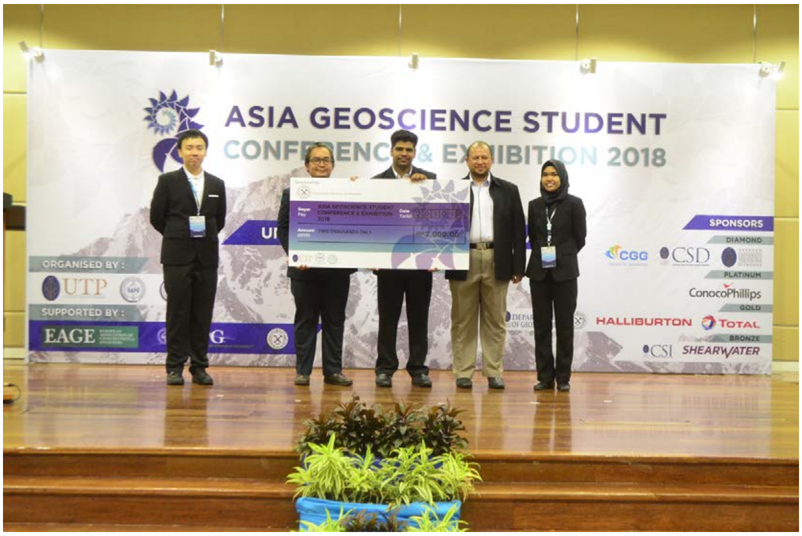
True to its theme "**Fueling Geosciences, Mapping Careers"**; this event's conference keynote sessions and technical talks featured a roster of 14 experienced speakers and researchers. Together, they have presented their ideas and vast knowledge on the challenges faced in the world of geoscience, which presents itself as a platform for undergraduates and postgraduates to enrich themselves in preparation for their future careers. The topics cover a diverse spectrum, ranging from "Geophysics: Where Earth Science Meets Human Life." by Mr Koya Suto from Australian Society of Geophysicists to "Overcoming challenges across exploration, reservoir and well placement lifecycles with Decision Space Geoscience" by Halliburton. Due its rarity in the ASEAN region, combined with the number, quantity, and as well as quality of the conferences, this initiative proved its worth by attaining full attendance for all sessions, leaving all attendees with a remarkable and unprecedented insight and experience.

AGSCE 2018 also conducted several competitions which include Geological Outcrop Model Exhibition, Poster & Oral Presentations, and the Geoquiz Competition. Two teams from Chulalongkorn University, Thailand has obtained the laurel for both the Outcrop Exhibition Competition and the Geoquiz Competition. Bintang Rajasanegaran of Bandung Institute of Technology (ITB), Hanistyas Widoretno of Universitas Pembangunan Nasional (UPN), Chin Say Han of Universiti Teknologi PETRONAS, Malaysia and Dhara Adhnanya Kumara of Universitas Indonesia, have achieved success by claiming victory in Oral Presentation Competiton, Poster Competition, Geophysics Oral Presentation, and Geophysics Poster Competition respectively. The aim of these activities is to serve as channels for the participants to apply and present their capabilities, knowledge, and ideas.

We would like to thank AGSCE 2018 sponsors, CGG, ConocoPhillips, TOTAL, Halliburton, Geological Society of Malaysia and Shearwater for the support and commitment in developing the future geoscientists across the region. AGSCE would also like to express our appreciation to Sathes Kumar, project director who pioneered and successfully completed the first edition of the conference. Our great success is largely due to the tremendous support which

we received from supporting professional organizations, sponsors and companies. The large presence of the event sponsors and supporting organisations has created a unique platform of networking and businesses opportunities all the participants. The large presence of the event sponsors and supporting organisations has created a unique platform of networking and businesses opportunities all the participants, in which it has accumulated more than 19 hours. In tandem with the goal of networking, AGSCE 2018 organised Networking Dinner, which provided both the delegates and the industry professionals to be able to establish ties with one another, in a relaxing manner.

AGSCE brings together industry professionals, academicians, and students from all over the Asia-Pacific region to Universiti Teknologi PETRONAS; to create a sense of community and facilitate the spirit of sharing and knowledge enhancement by offering an excellent environment for networking, promotions across national, scientific and career boundaries in the region. The second edition of AGSCE will be happening on 28-29 September 2019 highlighting the theme 'Evolving the World through Geoscience' at Universiti Teknologi PETRONAS, Malaysia. AGSCE 2019 aspires to be an open platform for presenting and exchanging new and innovative ideas between students of geosciences and industry experts around the Asia region in quest for continuous advancement in the field of geosciences. For more information on AGSCE 2019, please visit www.agsce.org.



UPCOMING EVENTS

April 30-May 1, 2019: Oklahoma Shale Production Optimization Congress Scoop and Stack 2019, Oklahoma City, USA. To find out more, visit site at: www.scoop-stack-production-optimization.com.

May 19-22, 2019: AAPG Annual Convention & Exhibition (ACE 2019), San Antonio, Texas, USA. For details, contact AAPG Customer Experience Center, T: +1 918 584 2555.

May 23-24, 2019: Offshore Conference Latin America 2019 (OCLA 2019), Buenos Aires, Argentina. Contact: Mike Ma, email: mike.ma@inforvalue.com.

May 27-31, 2019: International Course on Geotechnical and Structural Monitoring, Rome. Visit https://www.geotechnicalmonitoring.eu/participants-registration for further details.

June 17-19, 2019: The Energy in Data Conference, Austin, Texas, USA. For more information, please visit https://energyindata.org/.

June 23-25, 2019: 20th Asia Oil & Gas Conference, Kuala Lumpur, Malaysia. Discover more at aogc.com.my.

July 22-24, 2019: Unconventional Resources Technology Conference (URTec 2019), Denver, Colorado. Visit webpage https://urtec.org/2019 for further information.

August 7-8, 2019: The Art of Hydrocarbon Prediction: Managing Uncertainties (Technical Symposium), Bogor, Indonesia. Find out more at https://www.aapg.org/global/asiapacific/events/workshop.

August 26 - 28, 2019: EAGE/AAPG Workshop on Reducing Exploration Risk in Rift Basins, Kuala Lumpur, Malaysia. Visit the event page at https://events.eage.org/en/2019/eage-aapg-workshop-on-rift-basins for more details.

August 27-30, 2019: International Conference & Exhbition (ICE 2019), Buenos Aires, Argentina. Visit website for details, https://buenosaires2019.iceevent.org/.

September 11-13, 2019 (conference) and September 9-10 & 14, 2019 (workshops): European Conference on Mineralogy and Spectroscopy (ECMS 2019), Prague (Břevnov Monastery), Czech Republic. For details, visit http://ecms2019.eu; email: info@ecms2019.eu.

September 25-27, 2019: Regional Geoheritage Conference 2019, Kuching, Sarawak, Malaysia. For more information, please download: Regional_Geoheritage_Conference_2019.pdf461.58 KB13/02/2019, 06:28.

October 3-4, 2019: Workshop on the use of the electron probe microanalyzer (EPMA) with particular emphasis on modern developments and geological applications. For MSc students, PhD students, postdoctoral researchers and early career scientists from across the EU and beyond. Agricultural University of Athens, Athens, Geece. Visit website https://ibaziotis7.wixsite.com/epmaathens2019 for more details.

October 10-13, 2019: Euro-Mediterranean Conference for Environmental Integration (EMCEI), Sousse, Tunisia. Kindly contact the event organizer at www.emcei.net/ contact@emcei.net for clarifications.

October 29-30, 2019: Asia Petroleum Geoscience Conference & Exhibition (APGCE), Kuala Lumpur, Malaysia. For more details, please visit http://www.apgce.com/.

November 4-8, 2019: Africa Oil Week, Cape Town, South Africa. More details can be found at https://www.africa-oilweek.com/Home.

November 18-20, 2019: International Congress on Earth Sciences in SE Asia (ICES 2019), Bali, Indonesia. Visit website http://fos.ubd.edu.bn/foscon/ for more information.

January 13-15, 2020: International Petroleum Technology Conference (IPTC), Dhahran EXPO, Dammam, Saudi Arabia. Visit event website at https://www.2020.iptcnet.org to learn more about the conference.

March 16-19, 2020: 14th Middle East Geosciences Conference and Exhibition, Bahrain. To find out more, visit website https://geo-expo.com/conference/.

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KANDUNGAN / CONTENTS

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DECEMBER 2018 No. 66

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

Author's Address

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

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Abstract in both Malay and English, each in one paragraph and should not exceed 300 words. It should clearly identify the subject matter, results obtained, interpretations discussed and conclusions reached.

Keywords

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

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

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Chapter of book and Symposium volume:

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

Article in Malay:

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

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KANDUNGAN (CONTENTS)

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