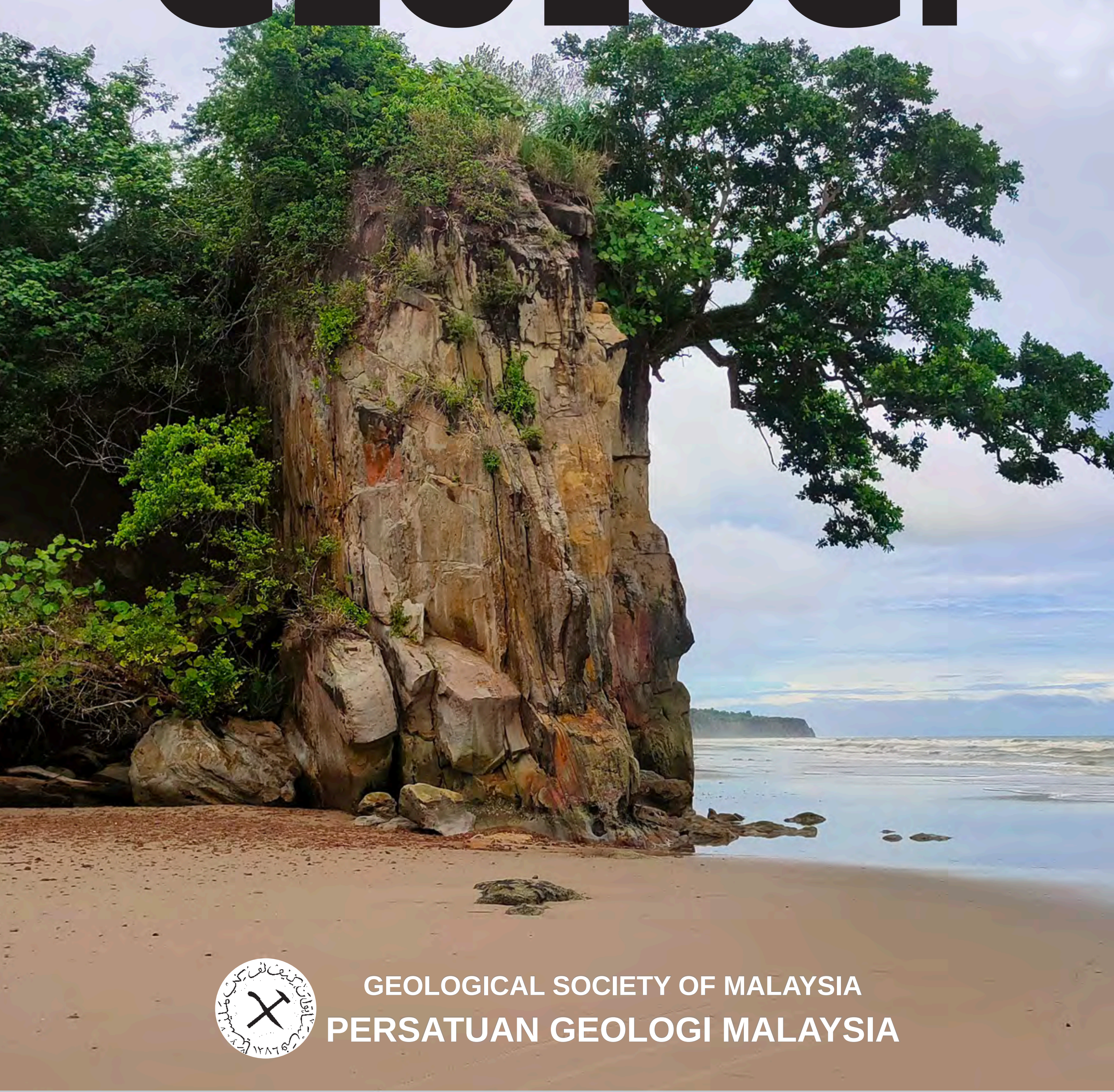
WARTA GEOLOGI



GEOLOGICAL SOCIETY OF MALAYSIA

PERSATUAN GEOLOGI MALAYSIA

Jilid 48 No. 3	December 2022	Volume 48 No. 3

ISSN 0126 - 5539; e-ISSN 2682 - 7549

PP2509/07/2013(032786) RM 80.00

The Geological Society of Malaysia (GSM) was founded in 1967 with the aim of promoting the advancement of geoscience, particularly in Malaysia and Southeast Asia. The Society has a membership of about 700 geoscientists based in Malaysia as well as abroad.

Warta Geologi is published three times yearly (April, August, December) by the Society. Warta Geologi publishes peer-reviewed short geological communications and original research on Earth Science. The scope includes local and regional geology, conservation geology, economic geology, engineering geology, environmental geology, geochemistry, geomorphology, geophysics, hydrogeology, palaeontology, petroleum geology, sedimentology, stratigraphy, structural geology and tectonics. Warta Geologi also reports on activities and news about GSM and the geoscience community in Malaysia.

Warta Geologi is distributed free-of-charge to members of the Society and is available free online through the Society's website: www.gsm.org.my.

GSM is committed to upholding standards of ethical behaviour at all stages of the publication process and we recommend the Committee on Publication Ethics (COPE) Best Practice Guidelines (http://publicationethics.org/resources/guidelines).

Further information can be obtained from:

The Editor,
Geological Society of Malaysia,
c/o Department of Geology, University of Malaya,
50603 Kuala Lumpur, Malaysia
Tel: 603-79577036 Fax: 603-79563900
Email: geologicalsociety@gmail.com

Warta Geologi

Cover photo: 90 degree vertically erected strata of Middle to Late Miocene Lambir sandstone, located immediately above the Middle Miocene Setap shale separated by the Mid-Miocene Unconformity (covered by vegetation), forming a steep cliff section between the Peliau and Tusan beaches, Bekenu. Photo credit to: Dr John Jong and Dr Franz Kessler

DOI : https://doi.org/10.7186/wg483202201

Does the Caribbean hold lessons for SE Asia? Part 1: The geology of Trinidad

Harry Doust

Department of Earth Sciences, Vrije Universiteit, De Boelelaan 1105, Amsterdam 1081 HV, the Netherlands
Author email address: harrydoust@hotmail.com

Abstract: Together with a second note (Warta Geologi, April 2023) I summarise the geological development of the island of Trinidad and the adjacent margins of the Caribbean Sea in order to compare them with parts of Southeast Asia. I believe the two provinces provide valuable analogues for each other and I illustrate this by considering examples of tectonic style taken from transpressional fold belts in Trinidad and eastern Java, from the evolution of foreland- and wrench basin stratigraphy and from striking similarities between the stratigraphy and structure of Borneo and Trinidad Tertiary continent margin deltas.

Keywords: Geological evolution, Trinidad, Java, transpression, Borneo, deltas

INTRODUCTION

The geological histories of Southeast Asia and the Caribbean have much in common (Figure 1). Almost uniquely, they share a Late Mesozoic to Tertiary evolution driven by active plate tectonics and are surrounded by subduction zones or wrenched plate boundaries. Both include continental margin sedimentary basins that record ongoing extensional and transpressional movements and include small ocean basins, several resulting from back-arc extension.

In this note I summarise the geology of Trinidad. In part 2 (to be included in Warta Geologi of April 2023) I consider some lessons we can perhaps take from comparing these two areas.

WHERE DOES TRINIDAD FIT IN THE CARIBBEAN?

Trinidad is situated at the south-eastern extremity of the Caribbean Sea, adjacent to the boundary between the Caribbean and South American plates (Figure 2). Its sedimentary basin evolution records the opening of the Central Atlantic, 'intrusion' of Pacific derived ocean crust into the gap between North and South America and the Tertiary collision along the margin of South America. In spite of its small size, nearly all of the elements that reflect Caribbean evolution come together here and it has contributed much to studies of the interplay between structural development and stratigraphic evolution.

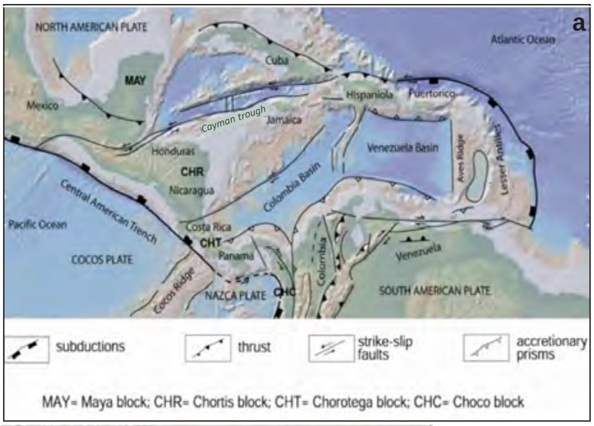
From the moment in 1595 when the notorious corsair Sir Walter Raleigh sent home reports of a huge lake of pitch in the southern part of the island, a tradition of geologic tourism grew and was succeeded in the 20th century by exploration for the petroleum resources. Among the most creative geologists to have worked there were Hans Kugler and Hans Bolli, who made ground-breaking advances in micro-palaeontological correlation in the post-war years and applied these to the interpretation of the complex subsurface structure.

What is most impressive is that so much geological variety is packed into this small area. The region appears to be so geologically rich and complex that, in spite of the extensive subsurface well data, it remains a huge challenge to unravel how structural and stratigraphic developments are linked.

SEDIMENTARY BASIN EVOLUTION AND TRINIDAD

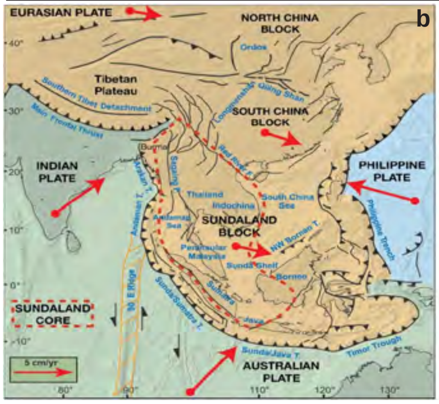
Sedimentary basin development can commonly be divided into distinct phases or cycles that reflect the evolution of the overall geodynamic environment. Many basins evolve from creation through crustal extension and subsidence (often associated with seafloor spreading), eventually to compression induced by plate collisions. Basins on the northern margin of South America follow such an evolution, complicated by extensive time-transgressive dextral wrench movements. Trinidad lies in a crucial location in this respect, since most of the collisional events are recent and the resulting geology is relatively "fresh", although complicated by extensive transpressive and transtensional shear deformation.

0126-5539; 2682-7549 / Published by the Geological Society of Malaysia.



Tectonic map of the Caribbean Plate (Colombian and Venezuelan basins). The surrounding deformed margins are dominated by large-scale wrench-induced inversion structures and island arcs bounded by opposing fold belts. The driving mechanism of basin evolution is the westward movement of the Atlantic Plate (including South and North America) relative to an essentially static Caribbean. Trinidad is situated at the SE corner of the Caribbean.

From Giunta and Orioli 2010, DOI:5772/18723



Tectonic map of Southeast Asia. As in the Caribbean, the area includes continental and arc-related terranes and ocean basins. Tertiary geological history was dominated by convergence of the Indian Ocean and Philippine Sea plates, accompanied by repeated transtensional back-arc extension. The province outer boundary is defined by a continuous active arc zone of subduction and transpression. (For a recent compilation of Caribbean Tertiary history see Geol. Soc. Sp. Publ., 328(2009).

From Metcalfe 2011, https://doi.org/10.1144/SP355.2

Figure 1: Tectonic maps of the Caribbean (a) and Southeast Asia (b), highlighting the similarities between their geodynamic frameworks.

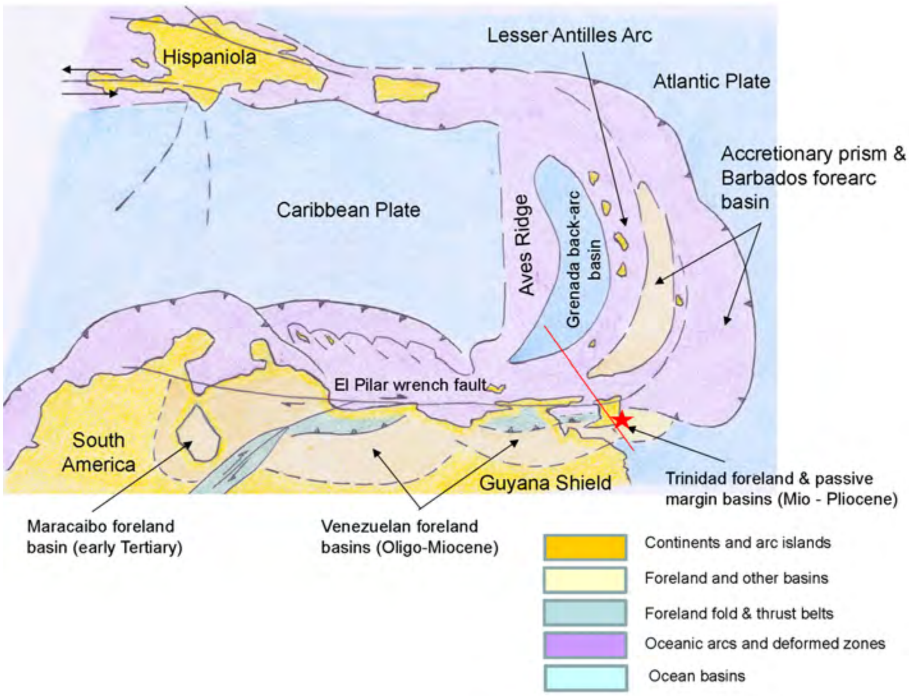


Figure 2: Geological province sketch map of the eastern Caribbean. The red line shows line of section Figure 3. Map not to scale.

CARIBBEAN EVOLUTION

Jurassic:

Opening of the North Atlantic was accompanied by the early break-up of Pangea, with rifting and drifting of North America away from South America. In the gap between North and South America, a Proto-Caribbean Ocean linked to the Atlantic developed which, by the Late Jurassic, was bounded to the south by a passive margin.

Cretaceous:

The South American plate started to be displaced westwards, triggering eastward subduction of the Pacific Ocean plate below its western margin. The Proto-Caribbean, however, started to subduct westwards below the Pacific Plate, producing an eastward-facing island arc (the Lesser Antilles). By the latest Cretaceous, the Pacific Plate started to over-ride the Proto-Caribbean and protrude between North and South America. As it did so, it became isolated between opposing subduction zones to form a separate plate, the (Neo) Caribbean Plate.

Early Tertiary:

The westward movement of the South American Plate led to a complex shear zone that progressed eastwards along the South American passive margin, reaching Trinidad in the Mio-Pliocene. Onshore, the shear zone is marked by wrenched compressional thrusts involving continent margin sequences accompanied by an eastward progressing foreland basin. North of Trinidad the Caribbean Plate grew through cycles of back-arc extension producing, for example, the Barbados Ridge and Basin (Figure 3).

Late Tertiary to Quaternary:

The Caribbean collision created a complex southward directed transpressive fold belt with an associated foreland cycle. Today the area is relatively stable and thick late Tertiary deltaic sequences derived from the Orinoco River accumulated in and around the evolving thrust belt.

SUMMARY EVOLUTION OF TRINIDAD

Pre-Mesozoic rocks are rare in the Caribbean area and younger events dominate the geology.

The Mesozoic to Quaternary evolution charts the progress from rift through post-rift sag into transpressive collision and post-compression cycles (Figure 2).

1. The rift cycle: Low-grade metamorphic rocks, including coaly sericitic phyllites and quartzites passing up into fossiliferous rudist limestones, cropping out in the Northern Ranges (Figure 4), possibly represent a Jurassic synrift cycle. Evaporites, found in the upper part, may correlate with Jurassic salt developments in and around the Gulf of Mexico.
2. The postrift cycle: During the Late Jurassic to Early Cretaceous thick sequences of deeper marine shales with limestones were deposited along much of the South American passive margin. Volcanics and submarine slumps reflect the proximity of Atlantic transform faults. By Late Cretaceous time abyssal conditions were established along the passive margin and bituminous shales were deposited. The postrift cycle continued into the Early Tertiary, where deep marine claystone and marls with turbidites dominate the sequence.
3. The transpressive collision cycle: By Mid-Tertiary times the eastward-progressing deformation margin of the Caribbean Plate had reached Trinidad. This resulted in the emergence of northern Trinidad, SSE-directed thrusting of the passive margin sequence associated with oblique transfer zones, and the formation of a deep marine foreland basin. As in other foreland situations sediments were now derived from

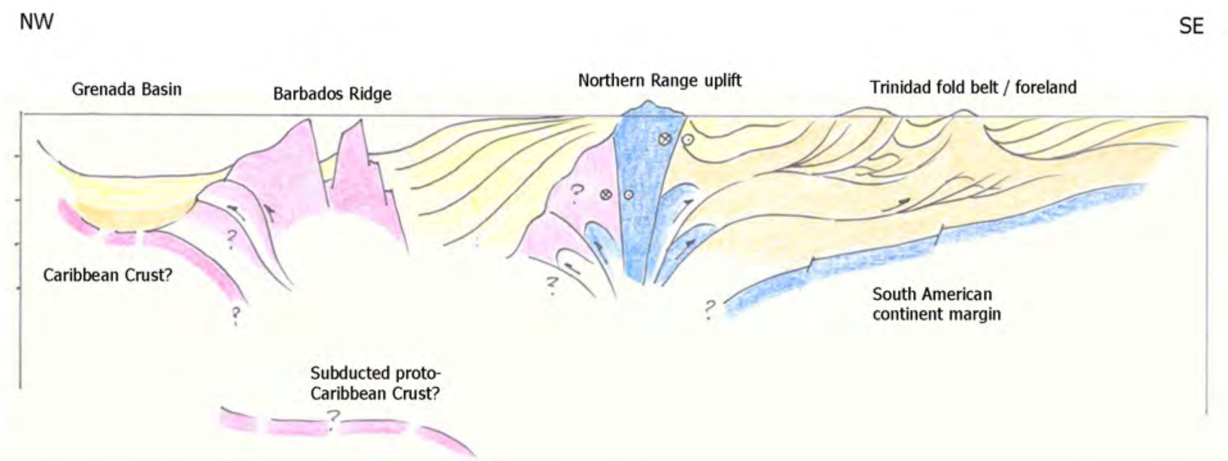


Figure 3: Sketched interpretation of structural provinces in the Trinidad area, compiled from various sources. Thicknesses approximate. The compressive wrench pop-up zone represented by the Northern Range has outward directed thrusts affecting both the Trinidad fold belt/foreland and the Barbados fore-arc ridge.

both the south (Orinoco River) and the uplifted zone to the north. The axis of deposition was displaced southwards through time and sediments filled the subsiding depressions, later to be sequentially incorporated in the southward migrating thrust belt. The foreland cycle sediments are highly argillaceous and under-compacted and often reach the surface as active mud volcanoes.

4. The post-tectonic foreland to passive cycle: Tectonic activity declined through the Pliocene and by the Quaternary was limited to wrench faulting and formation of a pull-apart basin, the Caroni Basin. A second passive margin cycle developed, and sediments from the Orinoco River prograded northwards and eastwards to build shallow marine deltaic sequences on and around Trinidad.

EVOLUTION OF THE FOLD BELT AND ITS INTERPRETATION

There are few places where a complex fold and thrust belt was investigated in such detail before seismic data became widely available. The abundance of the oil-bearing accumulations meant that dense grids of wells provided abundant subsurface coverage but unravelling the complexity of the structures meant that a sophisticated means to correlate formations was needed. This came from micro-palaeontological studies and the creation of a Tertiary planktonic foraminiferal zonation (Bolli *et al*., 2007). Interpretations of the subsurface structure and stratigraphy could now be made. Cross sections published by Kugler (1996) and his colleagues (Figure 5) showed enormous insight in resolving the structural complexity of oblique transpression affecting under-compacted sequences. They have stood the test of time and are largely confirmed by subsequent seismic data. Particularly impressive are early insights into the interplay between structural development and sedimentation, seen in many of the interpretations of the oil fields.

- Northern Range. The Northern Range constitutes a major sheared and uplifted dextral wrench zone, involving syn- and early postrift cycles, probably aligned along the northern boundary of the South American crustal block. The zone appears to form a flower structure associated with the El Pilar fault, with both northward and southward thrusts. Lateral slip along this fault is probably extensive, including 10 km of dextral slip during the Pleistocene.
- Caroni Basin. This represents the eastern extension of the Gulf of Paria, a pull-apart basin created at the end of the Miocene (~5Ma) at a releasing bend between ENE-WSW wrench faults. Prior to its recent history, this formed a piggy-back basin filled with Miocene (largely fluvial?) sediments overlying pre-Cretaceous rocks. Seismic data show an essentially symmetrical thick sediment fill locally inverted by transpression.
- Central Ranges and Naparima Hill thrust zone. The Central Ranges comprise a very complex zone of stacked imbricates involving the passive margin and foreland cycle sequences. Recent interpretations using seismic data indicate that the complexity may

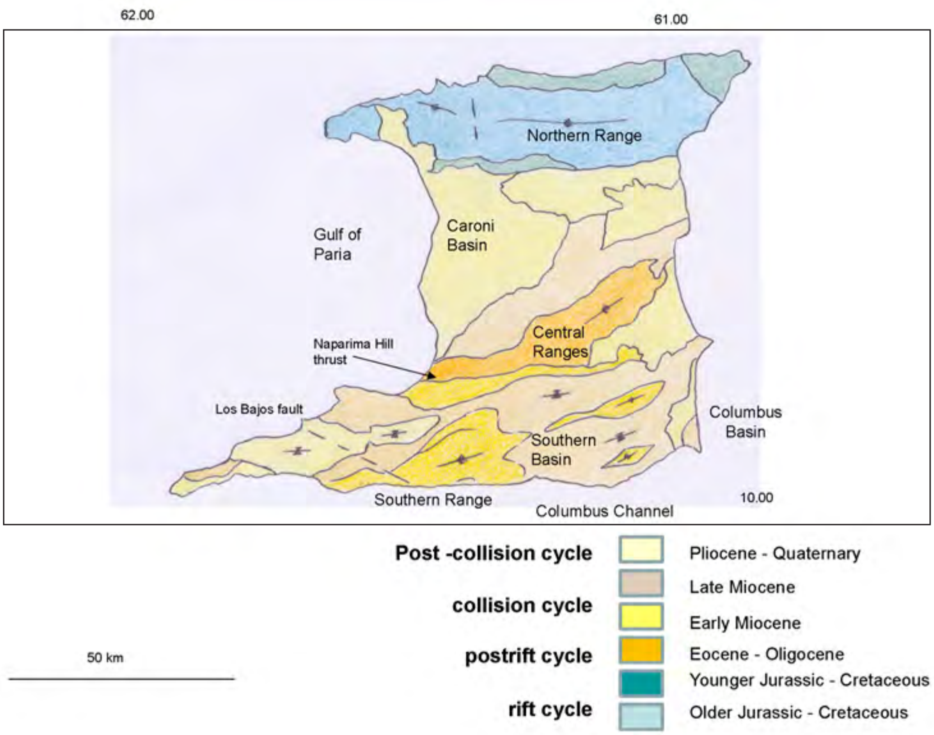


Figure 4: Sketch map of Trinidad geology, from various sources.

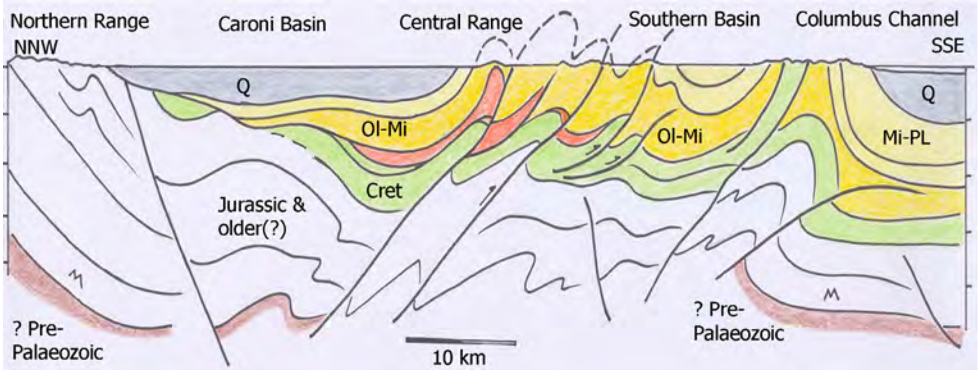


Figure 5: Simplified NNW – SSE section across Trinidad based on the insights of Kugler showing the transpressional foreland cycle basin. Re-drawn from: Kugler, 1996.

be greater than originally envisaged, with extensive wrench-induced Plio-Pleistocene out-of-sequence thrusting modifying earlier-formed structures. The concentration of such trusts may suggest that the area overlies a stepped basement, a possibility that is supported by the fact that the thrust with the greatest displacement, the Naparima Hill thrust (which brings Cretaceous rocks to the surface), extends eastwards into the offshore wrench zone of the Darien Ridge.

- Southern Basin. A shallow Pliocene piggy-back basin overlies complex out-of-sequence thrusts involving Oligo-Miocene and older rocks. As in the adjacent provinces, abundant evidence for structural detachment is seen on seismic profiles and extensive decollement horizons are probably present in the Late Cretaceous and early - middle Tertiary. Many of the oil fields lie in this zone, in complex Miocene imbrications complicated by clay diaprism. Pleistocene activity is restricted to wrench movement along the Los Bajos fault and back-thrusting.
- Southern Range. Much of this recently deformed zone probably represents inverted foreland /piggy-back cycles involving Late Miocene and Pliocene rocks. Folds are elongate with faulted axial plunges, often accompanied by Pleistocene cross-faults with clay diapirs. The southern limit is interpreted to constitute a back-thrust, probably marking the southern limit of the Trinidad fold belt and resembling the “triangle zone” at the deformation front of many fold belts. If so, this would imply that the sequence in the Columbus Channel is largely un-deformed and constitutes the present-day foreland cycle.
- Columbus Channel and Columbus Basin. In these areas thick sequences of Pliocene to Quaternary sediments derived from the eastward-prograding Orinoco Delta were deposited. The Columbus Basin delta is comparable to other Tertiary deltas such as those in West Africa (Niger Delta) and in SE Asia (Mahakam and Baram deltas), with prograding sequences affected by rows of NNW-SSE trending synsedimentary growth faults (Leonard, 1983). The delta sequence is underlain by NNE-SSW trending faults in the Cretaceous basement and where the growth faults cross these, anticlinal culminations formed in the late Pliocene.

In the second note I ask which aspects of Trinidad’s geology could be relevant to the regional evaluation of Southeast Asian Tertiary basins.

ACKNOWLEDGEMENTS

I am grateful for the opportunity I have had to study these fascinating areas and am indebted to those who enabled me to indulge in my attempts to rationalise their basin evolution for myself! Constructive comments from two anonymous reviewers are kindly acknowledged.

CONFLICT OF INTEREST

I declare that there is no conflict of interest in this note.

REFERENCES

Bolli, H.M., Beckmann, J.P., & Saunders, J.B., 2005. Benthic foraminiferal biostratigraphy of the South Caribbean region. Cambridge University Press, UK. 420 p.

Bolli, H.M., Saunders, J.B., & Perch-Nielsen, K., 2007. Plankton stratigraphy, volume 1 and 2. Cambridge University Press, UK. 608 p.

Cross, N.E., Zana K. Williams, Arman Jamankulov, Candice E. Bostic, Valini C. Gayadeen, Helisaul J. Torrealba, & Elizabeth S. Drayton, 2015. The dynamic behaviour of shallow marine reservoirs; insights from the Pliocene of offshore North Trinidad. Amer. Assoc. Petrol. Geols. Bull., 99, 555-583.

Giuseppe Giunta, & Silvia Orioli, 2011. The Caribbean Plate evolution: Trying to resolve a very complicated tectonic puzzle. In: Evgenii V. Sharkov (Ed.), New frontiers in tectonic research - General problems, sedimentary basins and island arcs. IntechOpen, London. 368 p. https://doi.org/10.5772/18723.

Kugler, H., 1996. Treatise on the geology of Trinidad. Natural History Museum of Basel, Basel.

Kugler, H.G., 2001. Treatise on the geology of Trinidad: Paleocene to Holocene Formations. Edited by H.M. Bolli & Knappertsbusch, M. Natural History Museum Basel, Birkhäuser Verlag Basel. 309 p
Leonard, R., 1983. Geology and hydrocarbon accumulations, Columbus Basin, offshore Trinidad. AAPG Bulletin, 67(7), 1081-1093.
Metcalfe, I., 2011. Palaeozoic–Mesozoic history of SE Asia. Geological Society, London, Special Publications, 355, 7 – 35. https://doi.org/10.1144/SP355.2.
Rohr, G.M., 1991. Exploration potential of Trinidad and Tobago. Jl Petr. Geol., 14(3), 343-354.
Wood, L.J., 2000. Chronostratigraphy and tectonostratigraphy of the Columbus Basin, eastern offshore Trinidad. AAPG Bull., 84(12), 1905-1928.

Manuscript received 28 May 2022;
Received in revised form 5 December 2022;
Accepted 6 December 2022
Available online 30 December 2022

DOI : https://doi.org/10.7186/wg483202202

Characterizing a weathering profile over quartz-mica schists in undulating terrain in Peninsular Malaysia

John Kuna Raj

No. 83, Jalan Burhanuddin Helmi 2, Taman Tun Dr. Ismail, 60000 Kuala Lumpur, Malaysia
Email address: jkr.ttdi.tmc@gmail.com

Abstract: The weathering profile can be differentiated into an upper, 4.8 m thick, pedological soil (zone I) and a lower, >16.2 m thick, saprock (zone II). Zone I comprises thin IA and IB soil horizons of firm, clayey sand with lateritic concretions, and a IC soil horizon of stiff, clayey silt with quartz clasts and lateritized core-stones. Zone II comprises steeply dipping to vertical, bands of pinkish to grey, stiff silt with distinct relict foliation (highly weathered schist) inter-fingering with bands of reddish yellow, firm clayey silt with indistinct foliation (completely weathered schist) towards its top, and bands of white to light grey, hard silt with distinct foliation (moderately weathered schist) towards its bottom. Lateral variations in abundance of differently weathered schist and preservation of fracture planes allow zone II to be separated into IIA, IIB and IIC sub-zones. The pedological soil (zone I) can be correlated with Class VI of standard rock mass weathering classifications, whilst the saprock sub-zones IIA, IIB and IIC are correlated with Classes V, IV and III, respectively. Silt fractions in the profile consist predominantly of sericite flakes, whilst the sand fractions are mostly of quartz grains and the clay fractions of mainly illite and kaolinite. Decreasing densities, unit weights and silt contents up the profile, but increasing porosities and clay contents, indicate increasing *in situ* alteration of the schist bedrock. Lowering of an unconfined groundwater table as a result of down-cutting by rivers in adjacent valleys is considered responsible for development of the weathering profile.

Keywords: Quartz-mica schists, weathering profile, schist weathering stages, weathering zones

INTRODUCTION

Several schemes have been proposed for the classification of rock mass weathering; one of the earliest by Moye (1955) who applied seven recognition criteria, including the staining of joints, decomposition of feldspars and absence of original texture, to distinguish six grades or degrees of weathering of granite in Australia. In Hong Kong, Ruxton & Berry (1957) differentiated four weathering zones within an idealized weathering profile over granite on the basis of the absence of original texture, staining of fractures and percentage occurrence of core-stones. Several other characterizations of weathering profiles over granitic bedrock, as those by Little (1969), Deere & Patton (1971), Lan *et al*. (2003) and Rahardjo *et al*. (2004) have also involved the differentiation of weathering zones based on essentially morphological criteria.

Some criticism, however, has been levelled at the use of weathering zones for geotechnical purposes, as their recognition is said to be based on criteria that is not quantitative nor related to mechanical properties or engineering behaviour of material (Dearman, 1974). Stages of weathering of granitic rock material were then defined and used to differentiate grades of weathering in weathering profiles; the grades, in reality, applied to weathering zones (Dearman, 1976; Irfan & Dearman, 1978). The assignment of weathering grades is somewhat problematic for different stages of weathering of rock material are present at similar levels, as in the concentrically developed stages of weathering around core-stones and core-boulders (Dearman, 1976). The assignment of rock mass weathering grades is thus considered to be an averaging process dependent upon mapping scale; the resultant grades being proportions of different materials (i.e. rock materials at different stages of weathering) (Baynes *et al*., 1978).

In a review of several classifications of weathering of rock mass, as those by the Geological Society (GSL, 1977), the International Association of Engineering Geology (IAEG, 1981) and the International Society for Rock Mechanics (ISRM, 1981), Martin & Hencher (1986) were critical of the way in which the term *grade* was used both as a type of weathering of rock, and to classify a zone of heterogeneous rock mass. Martin & Hencher (1986) also noted the lack of definition or guidance for the description of rock material grades; in

0126-5539; 2682-7549 / Published by the Geological Society of Malaysia.

particular, the inadequate definition of the terms *rock* and *soil*. Lee & de Freitas (1989) then proposed that the term weathering zone be used to distinguish the character of material *en-masse*, while the term weathering grade is used to describe material from which the mass is formed. From a study of weathered granite in Korea, Lee & de Freitas (1989) concluded that it is necessary to combine geological descriptions with mechanical evaluation to describe weathered materials; this necessity being especially important for identification of relict geological structures as joint and fault planes (Raj, 2009).

In the humid tropics, as Peninsular Malaysia, deep weathering profiles are found due to prolonged sub-aerial exposure throughout a larger part of the Cenozoic era (Raj, 2009). Standard classifications of rock mass weathering as those by the International Association of Engineering Geology (IAEG, 1981) and the International Society for Rock Mechanics (ISRM, 1981) thus require considerable modification when applied to weathering profiles over meta-sedimentary bedrock in the Peninsula due to their continuous weathering to form residual soils (Komoo & Mogana, 1988). The total absence of fresh meta-sedimentary bedrock at surface outcrops, and in boreholes, also makes it difficult to define the boundary between rock and soil and thus disallows use of *rock:soil* ratios for classification of weathering (Komoo & Mogana, 1988). In sub-tropical Queensland, it has also been pointed out that not all six classes of the standard weathering classification of rock mass of the International Society for Rock Mechanics (ISRM, 2007) were present at weathering profiles over the Bunya Phyllite (Marques & Williams, 2015). There was also an abrupt contact between soil and rock material with the layers of different classes of soil material being very thin, frequently less than 0.7 m (Marques & Williams, 2015).

In the course of a study on the characterization of weathering profiles in Peninsular Malaysia (Raj, 1983), was investigated a deep profile over quartz-mica schists in undulating terrain at Seremban in Negeri Sembilan State. In this article is discussed the characterization of the profile in terms of differentiating weathering zones, and in terms of differentiating rock mass weathering grades. Reasons for development of the weathering profile are also discussed.

GEOLOGICAL SETTING OF WEATHERING PROFILE

The weathering profile is located at the slope cut at Km 67.9 (southbound) of the Kuala Lumpur - Seremban Highway and was exposed during earthworks for its construction (Figure 1). The Highway here cuts through a low hill and trends in a general west to east direction

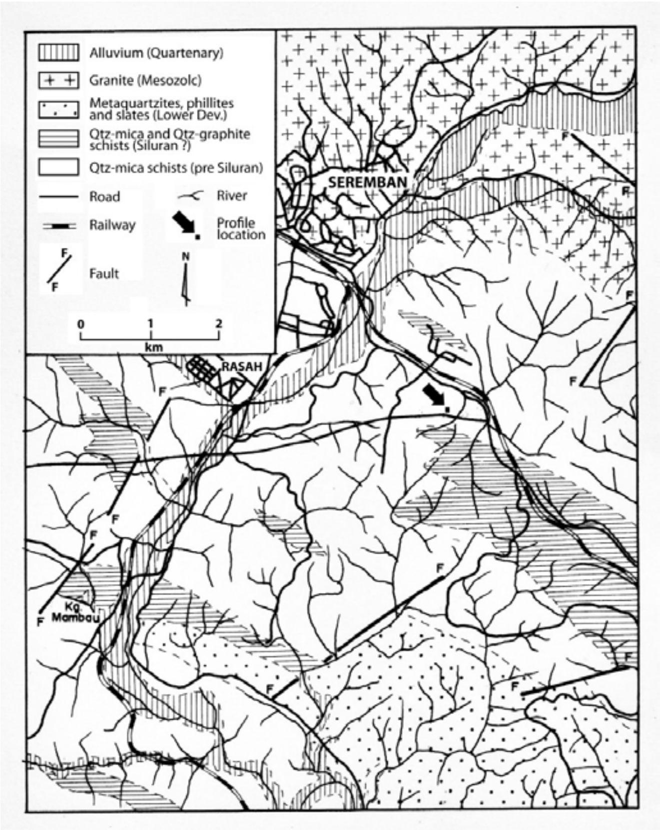


Figure 1: Geological sketch map of the Seremban area (after Khalid, 1972; Raj, 1993).

across an undulating terrain of low hills and ridges with narrow to broad, flat-bottomed valleys. The undulating terrain, located between some 50 and 100 m above mean-sea level, is developed over quartz-mica schists that have been correlated with the Lower Palaeozoic Dinding Schist of the Kuala Lumpur area (Khalid, 1972). The schists have an abundance of quartz lenses and pods and are highly deformed, whilst the flat-bottomed valleys are infilled with Quaternary alluvial sediments (Khalid, 1972; Raj, 1993).

Relatively less weathered bedrock at the base of the cut shows the weathering profile to be developed in light grey to buff, quartz-mica schists inter-layered with thin bands and lenses of dark grey, graphitic-quartz-mica schist (Photo 1). Indistinct to distinct preservation of the minerals and textures of the original schist in the exposed earth materials clearly indicates *in situ* development of the weathering profile. *In situ* development of the profile is further emphasized by the indistinct to distinct preservation of structural discontinuity planes inherent in the original bedrock material and mass, including foliation and fracture planes.

The relict foliation planes, though variable in detail, mainly strike north-south with very steep to vertical dips; an extremely fortuitous orientation for it allows variations in minerals and textures of individual lithologic units or sequences to be traced down-dip (i.e. down the profile). Lateral variations in relict minerals, textures and structures will therefore, reflect differences in lithologic units or sequences.

Photo 1: View of investigated weathering profile over quartz-mica schists.

In thin-sections, the relatively less weathered quartz-mica schist is seen to consist of thin layers (about 0.5 mm thick) of fine-grained quartz crystals in parallel alignment with thicker layers (up to 5 mm thick) of aligned sericite, muscovite and clay minerals. Relatively less weathered graphitic quartz-mica schist also shows a similar appearance, except for the presence of graphite in the thicker layers. In the thin-sections, secondary iron oxide and hydroxide stains and grains are often seen, whilst thin quartz veins and fissures are sometimes found perpendicular to the foliation.

Seepage was not seen at the cut, though perennial streams in adjacent valleys indicate the presence of an unconfined groundwater table at depth.

METHODOLOGY

The earth materials exposed at the cut were first described and mapped based on the Soil Survey Manual for Malayan Conditions (Leamy & Patton, 1966) and the Guidelines for Soil Description of the Food and Agriculture Organization (FAO, 2006). Pedological features described included colour, consistency and soil structure as well as the content of concretions, stains and organic matter. Geological features were also described and mapped, in particular the minerals, textures and structures of the original schist bedrock material and mass now indistinctly to distinctly preserved (as relict minerals, textures and structures) in the earth materials.

In order to better describe the earth materials present, constant volume samples were collected at various depths (Figure 2) to determine their physical and soil index properties. Brass tubes of 4 cm long and 7.6 cm internal diameter were used to collect the samples; the tubes having a constant wall thickness of 0.3 cm except

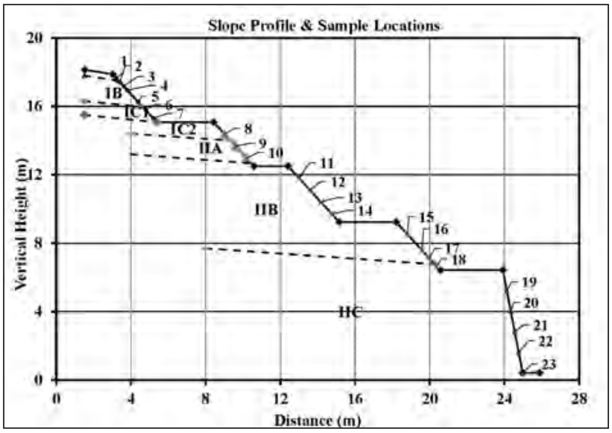


Figure 2: Slope profile and sample locations.

at one end where the lower half tapered to 0.15 cm thick to provide a cutting edge. Prior to sampling, the tubes were externally greased to facilitate entry into the soil while the surface materials were cleared to a depth of 0.3 m to minimize surface influences.

The sealed sampling tubes were taken to the laboratory where their moisture contents, unit weights and densities were determined before the specific gravity of the constituent mineral grains was measured using a pycnometer (ASTM, 1970). Porosities, void ratios and degrees of saturation of the samples were then calculated before the plastic and liquid limits of the fine fractions (<0.42 mm size) were determined (ASTM, 1970). Particle size distributions of the samples were next determined using the sieving, and sedimentation, methods for the coarse (>0.0625 mm diameter) and fine (<0.0625 mm diameter) grained fractions respectively (ASTM, 1970).

The main minerals present in the gravel, sand and silt sized fractions were then identified with the aid of a binocular microscope, whilst X-ray diffractograms of the clay fractions were prepared under normal, glycolated, and 500°C heated, conditions to determine the minerals present (Raj, 1993). It is to be noted that in view of a geological background, the size limits for particles follow the Wentworth (1922) Scale where gravel refers to particles with diameters between 2 and 64 mm, sand to particles with diameters between 0.0625 and 2 mm, silt to particles with diameters between 0.0039 and 0.0625 mm, and clay to particles less than 0.0039 mm in diameter.

RESULTS

Weathering zones and sub-zones

Vertical and lateral variations in the field mapped pedological and geological features allowed differentiation of the two upper zones of the pedo-weathering profile concept of Tandarich *et al*. (2002), i.e. the pedological soil, and saprock, zones. Several sub-zones can also be differentiated; the zones and sub-zones developed approximately parallel to the overlying ground surface (Table 1 and Figure 3).

The pedological soil (henceforth known as zone I) is some 4.8 m thick and comprises IA, IB and IC soil horizons (sub-zones); the IA and IB horizons constituting the solum, and the IC horizon, the saprolite. The IA and IB horizons are relatively thin and consist of yellowish red to red, firm clay and clayey sand with lateritic concretions, whilst horizon IC is 2.5 m thick and consists of reddish yellow, firm to stiff, clayey silt with vein quartz clasts

Table 1: Pedological and geological features of weathering zones and sub-zones.

Sub-zone	Thickness (m)	Pedological & Geological Features
IA	0.4	Yellowish red, firm clay with some roots and burrows.
IB	1.9	Red, firm clayey sand with abundant gravel sized lateritic concretions. Some lateritized core-stones and vein quartz clasts. Few roots.
IC1	1.3	Reddish yellow, stiff, clayey silt with some yellow mottles. Some gravel sized vein quartz clasts and lateritized core-stones.
IC2	1.2	Reddish yellow, firm clayey silt with some yellow mottles. Many gravel sized lateritized core-stones and vein quartz clasts. Distinct relict quartz veins and pods. Indistinct relict foliation. (Completely weathered schist).
IIA	2.2	Thick bands and wedges of reddish yellow, firm clayey silt with indistinct relict foliation (Completely weathered schist) alternating with thin bands of pinkish to grey, stiff silt with distinct relict foliation (Highly weather-ed schist). Distinct relict quartz veins and pods. Indistinct to distinct relict fracture planes. Some secondary iron stains and concretions along relict fracture planes. (Completely weathered schist >50% by area).
IIB	7.7	Thick bands of pinkish to grey, stiff silt (Highly weathered schist) alternating with thin bands of reddish yellow, firm clayey silt (Completely weathered schist). Towards bottom of sub-zone, some thin bands of white to light grey, hard silt (Moderately weathered schist). Distinct relict foliation and fracture planes as well as quartz veins and pods. Some iron concretions and stains along fracture planes. (Highly weathered schist >70% by area).
IIC	>6.3	Thick bands of white to light grey, hard silt (Moderately weathered schist) alternating with thin bands of pinkish to grey, stiff, silt (Highly weathered schist). Distinct relict foliation and fracture planes as well as quartz veins and pods. Rare secondary iron stains along fracture planes. (Moderately weathered schist >70% by area).

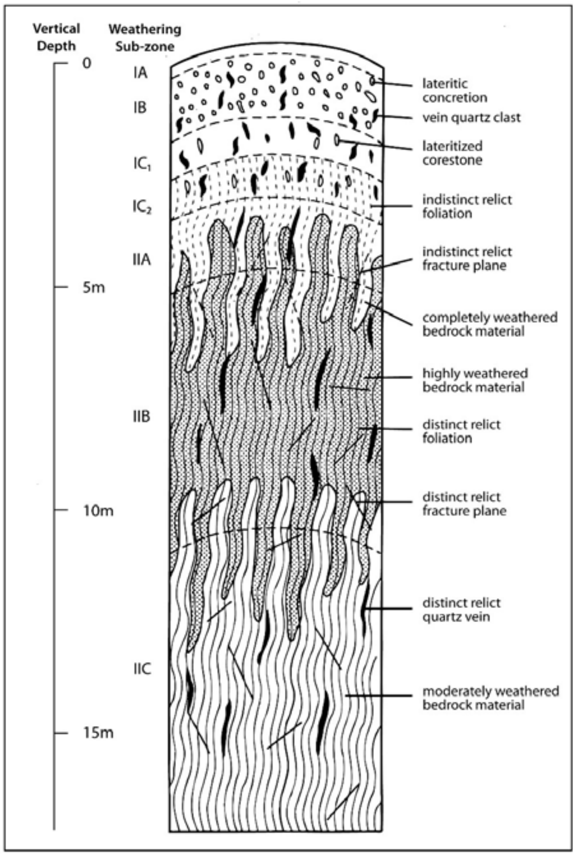


Figure 3: Schematic sketch of pedological and geological features in weathering profile.

and lateritized core-stones. The absence, or presence, of indistinct relict foliation planes furthermore, allows separation of the IC horizon into upper IC1, and lower IC2, sub-zones, respectively (Table 1 and Figure 3).

The saprock (henceforth known as zone II) is more than 16.2 m thick and consists of steeply dipping to vertical, alternating bands of white to light grey and pinkish to yellowish red, firm to stiff and hard, clayey silts and silts that indistinctly to distinctly preserve the minerals, textures and structures of the original schist bedrock material and mass. Bands of reddish yellow, firm clayey silt with indistinct relict foliation are prominent in the upper part of zone II and thus considered to represent completely weathered quartz-mica schist. Bands of white to light grey, hard silt with distinct relict foliation are prominent in the lower part of zone II and thus considered to represent moderately weathered quartz-mica schist. Bands of pinkish to grey, stiff silt with distinct relict foliation, are prominent in the middle of zone II and thus considered to represent highly weathered quartz-mica schist (Table 1 and Figure 3).

Lateral variations with depth in distribution of the bands of differently weathered schist, and preservation of fracture planes furthermore, allow Zone II to be differentiated into three sub-zones (Table 1 and Figure 3). The top IIA sub-zone is 2.2 m thick with indistinct relict fracture planes and comprises thick bands of completely weathered schist inter-fingering with thin bands of highly weathered schist; the completely weathered schist covering >50% by area. The intermediate IIB sub-zone is 7.7 m thick with indistinct to distinct relict fracture planes and consists of thick bands of highly weathered schist inter-fingering with thin bands of completely weathered schist; the highly weathered schist covering >70% by area. Thin bands of moderately weathered schist are also found inter-fingering with thick bands of highly weathered schist towards the bottom of sub-zone IIB. The lower IIC sub-zone is more than 6.3 m thick with distinct relict fracture planes and consists predominantly of thick bands of moderately weathered schist inter-fingering with thin bands of highly weathered schist; the moderately weathered schist covering >70% by area.

Physical properties of earth materials in the weathering profile

The earth materials show variations in physical properties that demarcate the different weathering sub-zones and reflect the increasing effects of weathering processes up the profile. Dry density ranges from 1,555 to 1,850 kg/m^3 and the dry unit weight from 15.25 to 18.15 kN/m^3 (Table 2). The zone II samples furthermore, show a general increase in dry density and unit weight with depth indicating decreasing density with increasing effects of weathering. The zone I samples, however, have more variable density and unit weights; the saprolite (sub-zone IC) having the maximum values of density and unit weight.

The specific gravity of soil particles is of limited variation; those of zone I ranging from 2.60 to 2.72, and those of zone II from 2.69 to 2.72 (Table 2). This limited variation is not unexpected in view of the closely similar range in specific gravity of the main mineral grains present. In zone I, the main minerals present are quartz with a specific gravity of 2.65, kaolinite with a specific gravity between 2.61 and 2.68, and sericite with a specific gravity between 2.77 and 2.88, whilst in Zone II there is in addition, illite with a specific gravity between 2.60 and 2.90 (Deer *et al.*, 1992).

Porosity is quite variable; the zone I samples with values of 32% to 40% and those of zone II from 29% to 34% (Table 2). Void ratios are similarly variable; the zone I samples with values of 0.48 to 0.67, and those of zone II with values of 0.41 to 0.53. A general decrease in porosity and void ratio with depth in zone II furthermore, indicates increasing porosity with increasing effects of weathering.

Moisture contents are quite variable; the topmost soil horizon IA with the highest content (16.5%) and sub-zone IIC with the lowest contents (4.3% to 7.5%)

Table 2: Physical properties of earth materials in the weathering profile.

Sub-zone	Sample	Vert. Depth (m)	Dry Density (kg/m^3)	Dry Unit Weight (kN/m^3)	S.G. Particles	Porosity (%)	Void Ratio	Water Cnt (%)	Degree Saturate (%)
IA	1	0.23	1555	15.25	2.60	40	0.67	16.5	64
IB	2	0.47	1776	17.42	2.65	33	0.49	10.6	57
IB	3	0.70	1796	17.62	2.65	32	0.48	7.0	39
IB	4	0.93	1750	17.17	2.72	36	0.55	8.2	40
IB	5	1.63	1762	17.29	2.72	35	0.54	7.6	38
IC1	6	2.10	1835	18.00	2.72	33	0.48	9.3	52
IC2	7	2.57	1708	16.75	2.72	37	0.59	14.1	65
IC2	8	3.50	1827	17.93	2.70	32	0.48	7.8	44
IIA	9	4.20	1827	17.92	2.70	32	0.48	5.5	31
IIA	10	4.90	1850	18.15	2.69	31	0.45	12.0	71
IIB	11	6.07	1770	17.36	2.70	34	0.53	6.3	32
IIB	12	6.77	1830	17.95	2.70	32	0.48	4.1	23
IIB	13	7.47	1810	17.76	2.70	33	0.49	6.1	34
IIB	14	8.17	1756	17.23	2.70	35	0.54	11.6	58
IIB	15	9.34	1832	17.98	2.70	32	0.47	5.8	33
IIB	16	10.28	1833	17.98	2.70	32	0.47	8.0	46
IIB	17	10.74	1814	17.79	2.70	33	0.49	7.9	43
IIC	18	11.71	1802	17.68	2.70	33	0.50	7.5	41
IIC	19	12.64	1877	18.41	2.70	30	0.44	4.4	27
IIC	20	13.85	1888	18.52	2.70	30	0.43	4.4	28
IIC	21	15.05	1855	18.19	2.70	31	0.46	7.5	44
IIC	22	16.25	1912	18.76	2.70	29	0.41	5.5	36
IIC	23	17.45	1776	17.42	2.70	34	0.52	7.0	37

Note: S.G. refers to Specific Gravity

whilst the other sub-zones have intermediate contents (4.1% to 14.1%). Degrees of saturation furthermore, show an exactly similar pattern as that of moisture contents (Table 2).

Soil index properties of earth materials in the weathering profile

Distinct variations in particle sizes are seen; the zone I samples with large clay fractions (>21%), and the zone II samples with large silt fractions (>52%) (Table 3). Sand fractions are more variable; large contents (32% to 48%) only present in the IB soil horizon which also has relatively large gravel fractions (10% to 14%). The relatively large sand and gravel fractions of the IB soil horizon are due to pedological processes that have given rise to the many lateritic concretions present. Zone II samples have very low gravel contents (<4%), though the sand fractions are very variable (0% to 16%); large sand fractions reflecting the presence of quartz pods and veins.

The zone II samples furthermore, show a general increase in clay contents up the profile (10% to 23%) but a corresponding decrease in silt contents (90% to 52%).

Table 3: Soil index properties of earth materials in the weathering profile.

Sub-zone	Sample	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Plastic Limit (%)	Liquid Limit (%)	Textural Weathering Index (I_w)
IA	1	0	27	30	43	25.3	64.1	0.59
IB	2	13	48	10	29	25.5	69.7	0.74
IB	3	11	32	34	23	23.9	69.7	0.40
IB	4	14	40	22	24	21.8	49.8	0.52
IB	5	10	46	23	21	19.9	49.8	0.48
IC1	6	1	1	73	25	22.2	47.8	0.26
IC2	7	0	14	59	27	26.5	43.0	0.31
IC2	8	0	3	76	21	25.2	33.5	0.22
IIA	9	0	12	71	17	28.2	id	0.19
IIA	10	0	2	89	9	29.5	id	0.09
IIB	11	0	37	52	11	26.8	id	0.17
IIB	12	0	5	85	10	25.7	id	0.11
IIB	13	0	12	65	23	26.3	id	0.26
IIB	14	0	7	75	18	23.5	id	0.19
IIB	15	0	2	88	10	25.3	id	0.10
IIB	16	0	8	77	15	26.6	id	0.16
IIB	17	0	1	81	18	24.4	id	0.18
IIC	18	1	16	71	12	25.3	id	0.14
IIC	19	0	0	88	12	30.0	id	0.12
IIC	20	4	13	68	15	27.0	id	0.18
IIC	21	0	0	90	10	25.9	id	0.10
IIC	22	1	7	82	10	25.6	id	0.11
IIC	23	1	3	86	10	26.9	id	0.10

Note: id refers to indeterminate

Increasing effects of weathering are thus marked by a general decrease in particle size; this feature reflecting increasing disintegration of the silt sized particles (Table 3).

Variations in consistency limits are less distinctive; the zone I samples with lower plastic limits (19.9% to 26.5%) than those of zone II (23.5% to 30%) (Table 3). Liquid limits could also only be determined for the Zone I samples (33.5% to 69.7%); the large silt contents of the zone II samples preventing the proper excavation of grooves in the Atterberg Device standard method of test.

Ratios of clay to total clay and silt contents, i.e. the Textural Weathering Index of Raj (2018), distinctly increase up the profile and reflect the increasing effects of weathering processes (Table 3). The earth materials of zone I with their relatively large clay contents are marked by large values (>0.22) of the Index, whereas those of zone II with their large silt contents are marked by lower values (0.10 to 0.18). Abrupt variations of the Index are seen in the zone II samples and reflect the local presence of quartz pods and veins that give rise to relatively large sand fractions.

Later stages of weathering of quartz-mica schist

The constant volume samples also show the moderately, highly, and completely, weathered quartz-mica schist (earlier defined from differences in colour and preservation of original minerals, textures and structures) to be characterized by differences in physical and soil index properties (Table 4). It is to be noted that these stages of weathering all involve *soil* material for the term *soil* is here considered to be *a natural aggregate of mineral grains that can be separated by such gentle means as agitation in water* (Terzaghi & Peck, 1948).

Binocular microscope examination of the silt fractions of the different stages of weathering shows them to consist exclusively of sericite flakes, whilst their sand fractions comprise fine quartz grains with some secondary iron oxide grains in highly and completely weathered schist (Table 4). Clay minerals in the different stages of weathering are variable; illite only present in moderately weathered schist but kaolinite and illite in highly weathered schist, and kaolinite with randomly interstratified illite-montmorillonite in completely weathered schist and pedological soil (Raj, 1993). Disintegration of muscovites and sericites in the original schist bedrock was thus considered to initially result in illite which was later transformed to kaolinite and randomly interstratified illite-montmorillonite through leaching (Raj, 1993).

DISCUSSION

Development of weathering profile

Differentiation of the pedological soil and saprock zones supports the view of Carroll (1970) that chemical weathering at the outer part of the lithosphere takes place in two stages; the first stage being the production of rotten rocks, on which the second stage, soil formation, takes place. The first stage is geochemical weathering, and is mostly the inorganic alteration of solid rocks, but in the second stage the effects of vegetation, both living and dead, together with the effects of metabolism of micro-organisms living in the geochemically altered rock materials, are added by the continued inorganic processes (Carroll, 1970). The pedological soil (zone I) is thus considered to result from alteration of the schist bedrock by both geochemical and pedological processes, whilst the saprock (zone II) results from inorganic alteration of the bedrock.

Recognition of these different processes is important, for a study of three deep weathering profiles over basalt, granite and schist (with depths to bedrock of 16, 27 and 10 m, respectively) showed them to have rather similar physico-chemical properties, despite differences in parent material (Hamdan & Burnham, 1997). Clay contents for instance, showed a decreasing trend with depth in all three profiles, whilst silt and sand contents showed an increasing trend with depth. Hamdan & Burnham (1997) thus concluded that the rain forests of the Peninsula over the old, deeply weathered soils had closed nutrient cycling systems where the cationic nutrients are in equilibrium with the main input from the atmosphere; there being negligible contribution of nutrients from weathering of bedrock.

The development of the weathering profile thus needs to take into consideration the geological history of the site and surrounding area. The present-day undulating terrain of low hills and ridges with meandering flat-bottomed valleys is clearly the result of down-cutting (incision) and lateral erosion by perennial rivers over eons of geological time. Down-cutting by rivers and the creation of valleys will give rise to a downward migration of unconfined groundwater tables in the adjacent hills and ridges. Lowering of the groundwater table will give rise to decomposition of the schist bedrock through various chemical reactions as hydrolysis, solution and the leaching of cations and anions. Lowering of the groundwater table

Table 4: Later stages of weathering of quartz-mica schist rock material.

Stage of weathering	Features
Completely weathered quartz-mica schist	Reddish yellow, firm clayey silt with yellow mottles and indistinct relict foliation. Material slowly disaggregates when dry samples are agitated in water. Coarse fraction of sericite flakes with some quartz and secondary iron oxide grains. Clay fraction of kaolinite and randomly interstratified illite-montmorillonite. Dry density 1.80 - 1.85 g/cc. Porosity 33 - 38%.
Highly weathered quartz-mica schist	Pinkish to grey, stiff silt with distinct relict foliation. Material readily disaggregates when dry samples are agitated in water. Coarse fraction of sericite flakes with some quartz and secondary iron oxide grains. Clay fraction of kaolinite and illite with some randomly interstratified illite-montmorillonite. Dry density 1.75 - 1.85 g/cc. Porosity 32 - 35%.
Moderately weathered quartz-mica schist	White to light grey, hard silt with distinct relict foliation. Material disaggregates when dry samples are agitated in water. Coarse fraction of sericite flakes with some quartz grains. Clay fraction of mainly illite with some poorly crystallized kaolinite. Dry density 1.80 - 1.92 g/cc. Porosity 29 - 33%.

also results in zones of aeration where other weathering reactions as oxidation and dehydration can occur.

Denudational processes (involving weathering and erosion) will give rise to decreasing overburden pressures on bedrock at depth and thus result in dilation (opening-up) along structural discontinuity planes, as foliation and fracture planes, in the schist bedrock. The overall impact of all these processes will be the disintegration and decomposition of the quartz-mica schists to variable depths below the ground surface.

Fluctuations in unconfined groundwater tables have also occurred in the area with deposition of alluvial sediments and formation of flat-bottomed valleys during aggradation as a likely result of Quaternary global sea-level changes (Raj, 2022). Softening and weathering of the schist bedrock will thus extend to considerable depths and account for the continuous weathering of meta-sedimentary bedrock to form residual soils and the total absence of fresh schist bedrock at surface outcrops; features earlier noted by Komoo & Mogana (1988).

Assignment of rock mass weathering grades or classes

Assigning rock mass weathering grades (IAEG, 1981; ISRM, 1981) or classes (ISRM, 2007) to the investigated weathering profile is difficult as the absence of fresh bedrock prevents definition of the boundary between rock and soil and does not allow use of *rock/soil* ratios (Komoo & Mogana, 1988). The pedological soil zone differentiated in this study (comprising sub-zones IA, IB and IC), however, can be directly correlated with rock mass weathering grade (or class) VI of the said schemes of classification (Table 5).

Minor differences in mineral compositions of the silt and sand fractions of the different stages of schist weathering indicate that there have only been minor mineralogical changes during weathering (Table 4). This is not unexpected for the main minerals in the original schist bedrock (ie. muscovite, sericite, quartz and graphite) are relatively stable under atmospheric conditions (Price, 1995). Disintegration of the muscovites

Table 5: Rock mass weathering class (ISRM, 2007) and weathering sub-zones.

Rock Class	Sub-zone	Thickness (m)	Pedological & Geological Features
VI	IA	0.4	Yellowish red, firm clay with some roots and burrows.
	IB	1.9	Red, firm clayey sand with abundant gravel sized lateritic concretions. Some lateritized core-stones and vein quartz clasts. Few roots.
	IC1	1.3	Reddish yellow, stiff, clayey silt with some yellow mottles. Some gravel sized vein quartz clasts and lateritized core-stones.
V	IC2	1.2	Reddish yellow, firm clayey silt with some yellow mottles. Many gravel sized lateritized core-stones and vein quartz clasts. Distinct relict quartz veins and pods. Indistinct relict foliation. (Completely weathered schist).
	IIA	2.2	Thick bands and wedges of reddish yellow, firm clayey silt with indistinct relict foliation (Completely weathered quartz-mica schist) alternating with thin bands of pinkish to grey, stiff silt with distinct relict foliation (Highly weathered quartz-mica schist). Distinct relict quartz veins and pods. Indistinct to distinct relict fracture planes. Some secondary iron stains and concretions along relict fracture planes. (Completely weathered schist >50% by area).
IV	IIB	7.7	Thick bands of pinkish to grey, stiff silt (Highly weathered quartz-mica schist) alternating with thin bands of reddish yellow, firm clayey silt (Completely weathered quartz-mica schist). Towards bottom of sub-zone, some thin bands of white to light grey, hard silt (Moderately weathered quartz-mica schist). Distinct relict foliation and fracture planes as well as quartz veins and pods. Some iron concretions and stains along fracture planes. (Highly weathered schist >70% by area).
III	IIC	>6.3	Thick bands of white to light grey, hard silt (Moderately weathered quartz-mica schist) alternating with thin bands of pinkish to grey, stiff, silt (Highly weathered quartz-mica schist). Distinct relict foliation and fracture planes as well as quartz veins and pods. Rare secondary iron stains along fracture planes. (Moderately weathered schist >70% by area).

and sericites, however, has been considered to initially result in illite that was later transformed to kaolinite and randomly interstratified illite-montmorillonite through leaching (Raj, 1993). Physical processes of weathering (ie. disintegration) are thus considered to be responsible for initial breakdown of the schist bedrock with further decomposition through leaching.

Notwithstanding the absence of fresh bedrock, recognition of the role of disintegration in weathering of the schist indicates that weathering sub-zones IIC, IIB and IIA (together with IC2) are best correlated with Classes III, IV and V, respectively, of the International Society for Rock Mechanics scheme for classification and description of rock mass (ISRM, 2007) (Table 5). The weathering zones and sub-zones differentiated in this study are thus equivalent to the weathering classes (as well as grades) of existing schemes for classification and description of rock mass.

CONCLUSIONS

It is concluded that pedological and geological features of the exposed earth materials, in particular the indistinct to distinct preservation of the minerals, textures and structures of the original schist, that allowed for characterization of the weathering profile. Two broad weathering zones were differentiated; an upper, 4.8 m thick, pedological soil (zone I) and a lower, >16.2 m thick, saprock (zone II). The pedological soil comprises thin IA and IB soil horizons of firm, clayey sand with lateritic concretions, and a IC soil horizon of stiff, clayey silt with quartz clasts and lateritized core-stones. The saprock (zone II) comprises steeply dipping to vertical, bands of pinkish to grey, stiff silt with distinct relict foliation (highly weathered schist) that inter-finger with bands of reddish yellow, firm clayey silt with indistinct foliation (completely weathered schist) towards the top (of zone II), and bands of white to light grey, hard silt with distinct foliation (moderately weathered schist) towards the bottom. Lateral variations in abundance of the differently weathered schist and preservation of fracture planes allowed zone II to be separated into IIA, IIB and IIC sub-zones.

Silt fractions in the weathering profile consist predominantly of sericite flakes, whilst the sand fractions are mostly of quartz grains and the clay fractions of mainly illite and kaolinite. Decreasing densities, unit weights and silt contents up the profile, but increasing porosities and clay contents, indicate increasing in situ alteration of the bedrock. Recognition of disintegration as a weathering process allowed the pedological soil (zone I) to be correlated with Class VI of standard rock mass weathering classifications, whilst the saprock sub-zones IIA, IIB and IIC are correlated with Classes V, IV and III, respectively. Lowering of an unconfined groundwater table as a result of down-cutting by rivers in adjacent valleys is considered responsible for development of the weathering profile.

ACKNOWLEDGEMENTS

Grateful thanks are extended to the University of Malaya for an F-Vote Research Grant that supported the field and laboratory work involved in the study. Grateful thanks are also extended to the two anonymous reviewers for their valuable comments on the initial submission.

CONFLICT OF INTEREST

The author has no conflict of interest to declare that are relevant to the content of this article.

REFERENCES

AASTM, American Society for Testing & Materials, 1970. Special Procedures for Testing Soil and Rock for Engineering Purposes. Special Publication 479, American Society for Testing and Materials, Philadelphia. 630 p.

Baynes, F.J., Dearman, W.R., & Irfan, T.Y., 1978. Practical assessment of grade in a weathered granite. Bull. Int. Assoc. Engineering Geol., 18, 101-109.

Carroll, D., 1970. Rock weathering. Plenum Press, New York. 203 p.

Dearman, W.R., 1974. Weathering classification in the characterization of rock for engineering purposes in British practice. Bull. Int. Assoc. Engineering Geol., 9, 33-42.

Dearman, W.R., 1976. Weathering classification in the characterization of rock: A revision. Bull. Int. Assoc. Engineering Geology, 13, 123-127.

Deer, W.A., Howie, R.A., & Zussman, J., 1992. An introduction to the rock forming minerals, 2nd edition. Longman Scientific & Technical, New York. 696 p.

Deere, D.V., & Patton, F.D., 1971. Slope stability in residual soils. Proceedings VI Pan-American Conference on Soil Mechanics and Foundation Engineering, Puerto Rico, 1, 87-170.

FAO, Food & Agricultural Organization, 2006. Guidelines for soil description, 40th edition. Food and Agriculture Organization of the United Nations, Rome. 109 p.

GSL, Geological Society of London, 1977. The description and classification of weathered rock for engineering purposes. Geol. Soc. Engineering Group Working Party Rept., Quart. J. Engineering Geol., 28, 207–242.

Hamdan, J., & Burnham, C.P., 1997. Physico-chemical characteristics of three saprolites in Peninsular Malaysia. Communications Soil Science & Plant Analysis, 28, 1817-1834.

IAEG, International Association for Engineering Geology, 1981. Rock and soil description for engineering geological mapping. Bull. Int. Assoc. Engineering Geol., 24, 235-274.

Irfan, T.Y., & Dearman, W.R., 1978. Engineering classification and index properties of a weathered granite. Bull. Int. Assoc. Engineering Geol., 17, 79-90.

ISRM, International Society for Rock Mechanics, 1981. Suggested methods for rock characterization testing and monitoring. Brown, E.T. (Ed.), Pergamon Press, Oxford. 211 p.

ISRM, International Society for Rock Mechanics, 2007. The complete ISRM suggested methods for rock characterization, testing and monitoring: 1974-2006. International Society for Rock Mechanics, ISRM Turkish National Group Ankara, Turkey. 628 p.

Khalid, B.N., 1972. Brief geology of the Seremban area, Sheet 103. Ann. Rept., 1972, Geological Survey of Malaysia, 86-93.

Komoo, I., & Mogana, S.N., 1988. Physical characterization of weathering profiles of clastic meta-sediments in Peninsular Malaysia. Proc. 2nd Int. Conf. Geomechanics in Tropical Soils, 12-14 Dec 1988, Singapore, 1, 37-42.

Lan, H.X., Hu, R.L., Yue, Z.Q., Fee, C.F., & Wang, S.J., 2003. Engineering and geological characteristics of granite weathering profiles in South China. J. Asian Earth Sciences, 21, 353-364.

Leamy, M.L., & Panton, W.P. 1966. Soil survey manual for Malayan conditions. Soil Science Division, Department of Agriculture Malaysia, Kuala Lumpur. 226 p.

Lee, S.G. & de Freitas, M.H., 1989. A revision of the description and classification of weathered granite and its application to granites in Korea. Quart. J. Engineering Geol., 22, 31-48.

Little, A.L., 1969. The engineering classification of residual tropical soils. Proc. 7th Int. Conf. Soil Mechanics & Foundation Engineering, Mexico, 1, 1-10.

Marques, E.A.G., & Williams, D.J., 2015. Weathering of Bunya Phyllite in Southwest Brisbane - A geotechnical approach. In: Ramsey, G. (Ed.), Proc. 12th Australia New Zealand Conf. Geomechanics, Wellington, New Zealand, 22-25 February 2015, 1-8.

Martin, C.P., & Hencher, S.R., 1986. Principles for description and classification of weathered rock for engineering purposes. In: Hawkins, A.B. (Ed.), Site investigation practice, Assessing BS 5930. Engineering Geology Special Publication 2, Geol. Soc. London, 299-308.

Moye, D.G., 1955. Engineering geology for the Snowy Mountains scheme. J. Inst. Engineers Australia, 27, 287-298.

Price, D.G., 1995. Weathering and weathering processes. Quart. J. Engineering Geol., 28, 243-252.

Rahardjo, H., Aung, K.K., Leong, E.C., & Rezaur, R.B., 2004. Characteristics of residual soils in Singapore as formed by weathering. Engineering Geol., 73, 157-169.

Raj, J.K., 1983. A study of residual soils and their slope cut stability in selected areas of Peninsular Malaysia. Doctor of Philosophy Thesis (Unpublished), Department of Geology, University of Malaya. 462 p.

Raj, J.K., 1993. Clay minerals in the weathering profile of a quartz-mica schist in the Seremban area, Negeri Sembilan. Pertanika, J. Tropical Agricultural Science, 16,129-136.

Raj, J.K., 2009. Geomorphology. In: Hutchison, C.S., & Tan, D.N.K. (Eds.), Geology of Peninsular Malaysia. University of Malaya & Geological Society of Malaysia, Kuala Lumpur, 5-29.

Raj, J.K., 2018. Physical characterization of a deep weathering profile over rhyolite in humid tropical Peninsular Malaysia. Geotech. & Geol. Engineering, 36, 3793-3809.

Raj, J.K., 2022. Why failures occur at soil cuts & natural ground slopes in granitic bedrock areas of Malaysia. Presentation, Geol. Soc. Malaysia & Inst. Geol. Malaysia. Kuala Lumpur, July 20, 2022.

Ruxton, B.P., & Berry, L, 1957. The weathering of granite and associated erosional features in Hong Kong. Bull. Geol. Soc. America, 68, 1263-1292.

Tandarich, J.P., Darmody, R.G., Follmer, L.R., & Johnson, D.L., 2002. Historical development of soil and weathering profile concepts from Europe to the United States of America. J. Soil Science of America, 66, 335-346.

Terzaghi, K., & Peck, R.B., 1948. Soil mechanics in engineering practice. John Wiley and Son Inc., Hoboken. 566 p.

Wentworth, C.K., 1922. A scale for grade and class terms for clastic sediments. J. Geology, 30, 377-392.

Manuscript received 26 July 2022;
Received in revised form 1 December 2022;
Accepted 8 December 2022
Available online 30 December 2022

GEOSEA / NGC 2022

Please visit : https://gsm.org.my/articles/xvii-geosea-2022/ to view the complete GEOSEA / NGC 2022 program book.

Link : https://gsm.org.my/articles/xvii-geosea-2022/

CERAMAH TEKNIK TECHNICAL TALK

Rainfall induced landslides in Malaysia

Mohd Asbi Othman
Date: 29 August 2022
Platform: Zoom / Facebook Live GSM

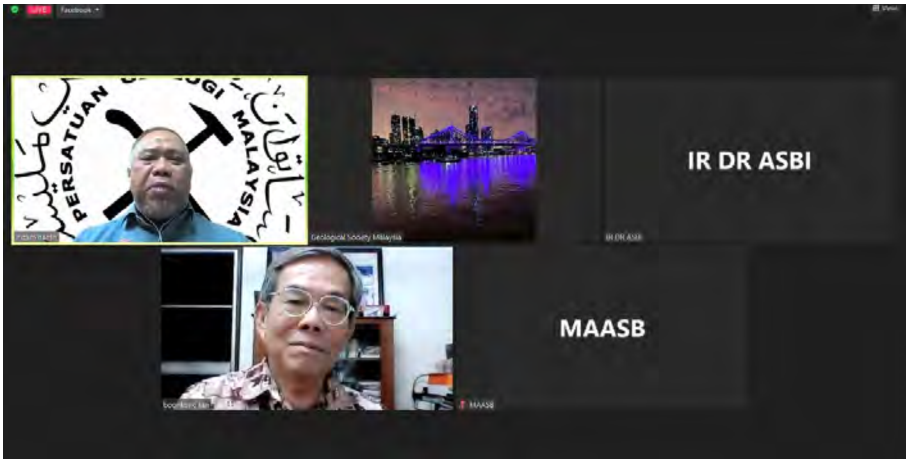
The above talk was delivered by Dato' Ir. Dr. Mohd Asbi Othman (Mohd Asbi & Associates) on 29th August, 2022, via Zoom/Facebook Live. Some 40 members participated. An abstract of the talk is given below:

Abstract: The majority of landslides in Malaysia and other tropical and sub-tropical countries are rainfall induced. These can be in the form of shallow and deep-seated slides, debris and mud flows, debris avalanches and rockfall depending on the topographical and hydrogeological conditions. It is useful to be able to correlate rainfall and landslide events in order to detrmine threshold levels for the formulation of effective warning systems. This presentation discusses some landmark landslides in Malaysia and their associated antecedent rainfall events. Other recent widespread landslides are also studied in terms of their susceptibility to rainfall.

Threshold levels which have been successfully used for early warning system in Malaysia are also discussed.

We thank Dato' Dr. Asbi for his support and contribution to the Society's activities.

Tan Boon Kong
Chairman, Working Group on Engineering Geology
30th August, 2022



CERAMAH TEKNIK TECHNICAL TALK

Usefulness of Cut Slope Stability Analysis – Should greater emphasis be on risk management?

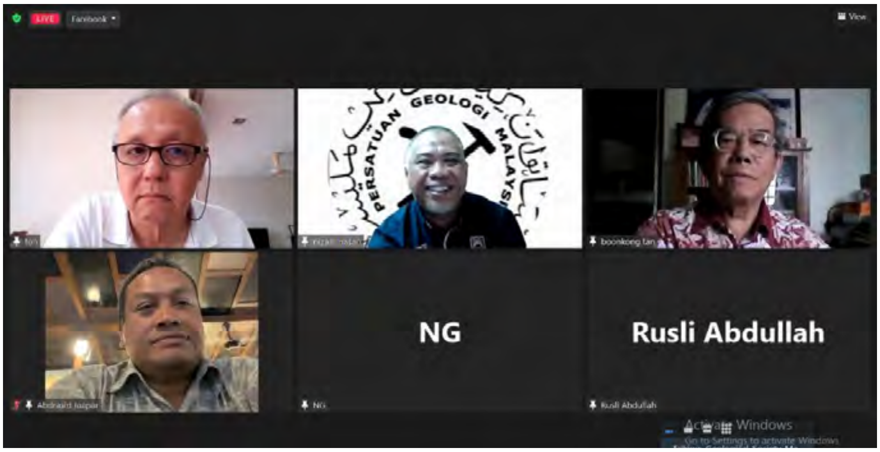
Toh Cheng Teik
Date: 21 September 2022
Platform: Zoom / Facebook Live GSM

The above talk was delivered by Ir. Dr. Toh Cheng Teik (Dr Toh & Associates) on 21st September, 2022, via Zoom/Facebook Live. Some 20 members participated. An abstract of the talk is given below:

Abstrak: Cut slope and natural slope stability.
The need to acknowledge the inadequacies and in many instances the uselessness of current limit equilibrium approach.
The need for risk management.
A much higher degree of geological input.
We will start with submission requirements, case histories of different types of slope failures and simple examples of risk management approach.

We thank Dr. Toh for his support and contribution to the Society's activities.

Tan Boon Kong
Chairman, Working Group on Engineering Geology
22nd September 2022



CERAMAH TEKNIK TECHNICAL TALK

Geological assessment of rock slope and limestone hill

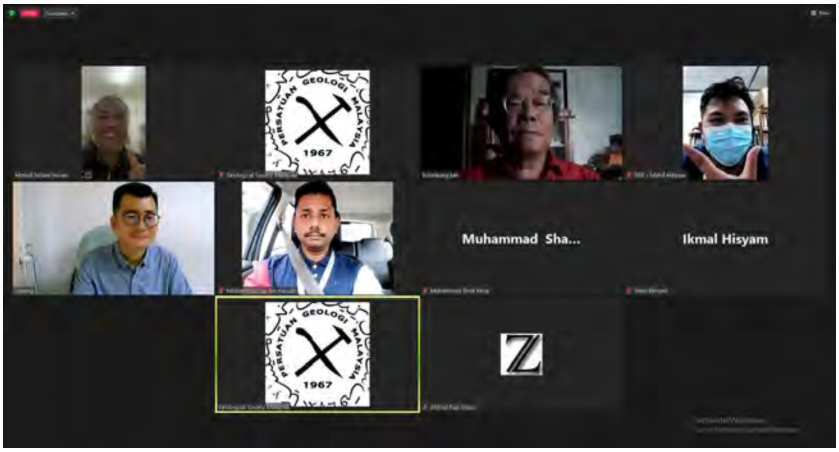
Philip Tiong Chong Ngu
Date: 16 November 2022
Platform: Zoom / Facebook

The above talk was delivered by P.Geol. Philip Tiong Chong Ngu (G&P) on 16th November, 2022, via Zoom/ Facebook Live. Some 50 members participated. An abstract of the talk is given below:

Abstract: Construction of highway and hill-site development always involve blasting or cutting rock slopes. Rock slope stability is governed by many factors such as lithology, weathering grade, structural discontinuities orientation, properties of discontinuities, rock mass quality, shear strength of discontinuities as well as the groundwater condition. Rock slope failures always happen in planar, wedge, and toppling modes of failure in geological structural planes and rock fall is also a common rock slope failure mode. When dealing with limestone hill stability, where limestone hills generally exist as vertical hilly terrain (karst landscape), the morphological features of the limestone cliff also play an important role in controlling the limestone hill's overall stability. Hence, there is a different methodology for carrying out geological assessment on a rock slope to study the rock slope stability and the hazard zone for limestone hill for development near limestone hill. This presentation presents the methodology for geological assessment of rock slope stability and limestone hills.

We thank Sdr. Philip for his support and contribution to the Society's activities.

Tan Boon Kong
Chairman, Working Group on Engineering Geology
16th November, 2022



CERAMAH TEKNIK TECHNICAL TALK

Ground evaluation and earthworks design for train depot in hilly area

Vigneshwaran Karunanidee and Nur Amanina Mazlan
Date: 21 December 2022
Platform: Zoom / Facebook

The above talk was delivered by Mr. Vigneshwaran Karunanidee and Pn. Nur Amanina Mazlan (MRTC) on 21st December, 2022, via Zoom/Facebook Live. Due to some technical problems, the GSM FB Live platform was not available, so only 12 persons participated via Zoom, comprising mostly staff of MRTC. Our sincere apology to GSM members who wanted but couldn't follow the talk via GSM FB Live. Video of the talk is available in the GSM FB/website for members who missed the talk.

An abstract of the talk is given below:

Abstract: A site located at Serdang adjacent to MARDI has been identified to be developed as a secondary MRT depot consisting of a central train maintenance building, depot control centre, stabling yard, administration building and associated infrastructures. One of the major challenges for this train depot is the site formation for a 155-acres levelled platform over hilly topography that includes hill slopes, valleys and low-lying areas. Geologically the site is underlain by Kenny Hill Formation which comprises of monotonous clastic sequence of interbedded shale, mudstone and thick bedded fine to medium grained sandstone. Comprehensive ground investigation programme, such as borehole exploration, geophysical survey, groundwater monitoring, etc. were carried out across the site to verify the subsurface conditions for geotechnical design as well as for control of ground-related risks in construction. Massive earthworks such as engineered fill platforms and high cut slopes were required to create the levelled platform due to the hilly terrain. The maximum fill height is about 36 m and the maximum cut slope height is about 55 m. Based on the available SI results and geological formation, the valley within the site is deposited by colluvium from adjacent hills and required ground treatment to eliminate excessive ground settlement upon placing the filling platform. This presentation will focus on ground investigation and evaluation carried out for earthworks design and construction. Earthworks good practices including the excavatability assessment to determine the rippability of hard soil and rock at cut areas will be discussed. The performance of the completed earthworks platform will be demonstrated with the readings collected from geotechnical instrumentation installed across the site.

We thank the speakers for their support and contribution to the Society's activities.

Tan Boon Kong
Chairman, Working Group on Engineering Geology
26th December, 2022

ASEAN Federation of Geoscience Organisations (AFGEO) Business Meeting 2022

Venue: Langkawi, Malaysia
Date : 17 & 18 October 2022

The Regional Congress on Geology, Minerals and Energy Resources of Southeast Asia, coined as GEOSEA, is a congress that acts as a platform for geoscience organizations of the ASEAN and Southeast Asia to meet on a regular basis in strengthening regional collaboration. The first GEOSEA was held in 1972 at the University of Malaya in Kuala Lumpur, Malaysia, and was organized by the four co-founding institutions: Geological Society of Malaysia (GSM), Ikatan Ahli Geologi Indonesia (IAGI), Geological Society of the Philippines, and Geological Society of Thailand. Since then, each co-founding institution took turns to host GEOSEA on a rotational basis.

In striving to define collaboration commitment among GEOSEA members, a Memorandum of Understanding (MoU) was drafted following the discussion in the GEOSEA Business Meeting in Hanoi, Vietnam in 2018. The MoU was signed online by Ikatan Ahli Geologi Indonesia (IAGI), Geological Society of Malaysia (GSM), Geological Society of the Philippines (GSP) and Geological Society of Thailand (GST) on 7th April 2021 to form the alliance named as ASEAN Federation of Geoscience Organisations (AFGEO). The GEOSEA will be maintained as the branding of flagship congress events.

The first AFGEO Business Meeting or formerly GEOSEA Business Meeting, this executive board meeting was conducted online on the final day of the 16th Regional Geoscience Congress of Southeast Asia 2021 (GEOSEA XVII) held on 6 – 8 December 2021 that was hosted by the Geological Society of the Philippines (GSP). The GEOSEA XVII congress and MoU signing ceremony initially planned for the year 2020 were postponed due to COVID19 pandemic.

The first physical meeting for AFGEO after the COVID19 pandemic was held on 17 October 2022 in Langkawi, Malaysia during GEOSEA XVIII, official MoU document exchanged was held on 18 October 2022 at the GEOSEA opening ceremony, as well as welcoming Myanmar Geoscience Society as a new signing member to the AFGEO MoU. In the Business Meeting, it was decided GSM to be appointed as the Permanent Secretariat of AFGEO, while the Chair and co-Chair of the Secretariat to be rotated based on next hosting countries of GEOSEA congress. The next GEOSEA Congress will be hosted by Geological Society of Thailand in 2024.

The meeting was attended by geoscience organisations from 5 countries namely Ikatan Ahli Geologi Indonesia (IAGI), Geological Society of Malaysia (GSM), Myanmar Geoscience Society (MGS), and Geological Society of the Philippines (GSP).

Prepared by:
Lim Choun Sian
GEOSEA/AFGEO Secretariat

NEW MEMBERSHIP

Student Membership

1. Abdul Hadi Hashim
2. Adedibu Sunny Akingboye
3. Adrian Taipau
4. Afiah Jasni
5. Ahmad Hamizan Made
6. Andrianah Anwar
7. Aslinda Balqis Amirul
8. Badrul Syahriamri Abd Kairul
9. Che Wan Nur Maisarah Che Wan Abdul Raffar
10. Clearin Johinis
11. Cruz Dee Chris Victor
12. Daniel Nur Haqeem Jumadi
13. Esthefenyvie Junip
14. Fatin Athirah Ghazali
15. Felicia Tinggal
16. Francis Paul Benjamin
17. Haimon Franklin
18. Hal Hasmi Mohamad Roslan
19. Haziq Ahmad Thajudeen
20. Iffa Maisarah Ahmad
21. Ilma Rahimah Alam Siah
22. Ivy Azlinda Mazreen Bahrin
23. Jane Sawat Perait
24. Jayeola Afolabi Olubunmi
25. Jilven Jiviky
26. Kassey Dairin Unsir
27. Kattily Grain
28. Khiri Abubakr M Khalf
29. Ledyhernando Taniou
30. Mohamad Izzul Haqim Mohamad Mohidi
31. Mohammad Syawal Fitri Zackaria
32. Mohammad Fudail Khair Saideh
33. Muhammad Afiq Syamim Adnan
34. Muhammad Alif Danial Suaud
35. Muhammad Ammar Ahmad Dahisam
36. Muhammad Danish Hakim Mohd Amin
37. Muhammad Mahathir Malik
38. Muhd Danial Hafizee
39. Muhd Izran Hafiz Ibrahim
40. Nadhirah Hanim Naim
41. Nor Syahirah Mohd Idris
42. Nur Adriana Najwa Zulkafli
43. Nur Al'lyn An-Nisryn Mohd Razif
44. Nur Liyana Mohd Dzulkifli
45. Nur Najwa Mohd Zuhid
46. Nur Syahkila Sabaruddin
47. Nurfarahin Amir Hamzah
48. Nurliyana Suraya M Azhar
49. Nurul Atiqah Ismuzarimi
50. Nurul Izzati Jakaria
51. Nurul Yannah Adnan
52. Owenny Ernny Jobinal
53. Prajeeva Rao Genganaidu
54. Shama Suresh Kumar
55. Sharifah Nur Nadhirah Wan Narudin
56. Siti Aisyah Ahmad Jamil
57. Syamil Syazwan Mohd Napsan
58. Thilaga Durai Kanna
59. Umie Assira Jamali
60. Yeong Wei Jian

Full Membership

1. Ahmad Zamzamie Ishak
2. Amal Najihah Muhamad Nor
3. Azman Abdullah
4. Dorani Johari
5. Fatin Izzati Minhat
6. Hareyani Zabidi
7. Khoong Tai Wai
8. Lin Chin Yik
9. Loo Hann Woei
10. Madlazim
11. Meunier Jea-Pierre
12. Mohamad Fardzuan Ahmad Shukri
13. Muhammad Faris Abdul Halim
14. Nurul Zainab Along
15. Siti Nurkhalidah Husainy

From Student To Full Membership

1. Adila Fateha Abdul Mudtalib
2. Azyan Syahira Azmi

From Full To Life Membership

1. Mohd Shafiq Firdauz Abdul Razak

Associate

1. Harris Aiman Mohd Noor Azmi

Report on SIMPOMIN 2022, 11th August 2022

10th SIMPOMIN 2022: NR-REE (Non-Radioactive Rare Earth Elements)

Place: Everly Hotel, Putrajaya
Organized by: Department of Mineral and Geoscience Malaysia,
Ministry of Energy and Natural Resouces

This SIMPOMIN was unlike the last one I attended (in 2019, Meru, Perak), where a variety of papers from attendees were presented. SIMPOMIN 2020 had a single theme - Rare Earth Elements (REE) hosted in deposits of ion-adsorption clays (IAC). This type of deposit is the world's main source of Heavy Rare Earth Elements (HREE), and has mainly been exploited in Southern China. In recent years, this type of deposit has also been discovered in Peninsular Malaysia, and with demand for REEs set to dramatically increase, an effort is currently under way to evaluate the extent of REE reserves available, and the issues associated with their exploitation.

REEs consist of the 15 Lanthanides, heavy metals with similar properties, grouped together on the Periodic Table, from Lanthanum (La, n=57) to Lutetium (Lu, n=71). In addition, Scandium (Sc, n=21) and Yttrium (Y, n=39) are also considered REEs, since they are often found together in the same deposits as the Lanthanides, have similar chemical properties, but different electrical and magnetic properties. Despite the name, they are not as uncommon in the Earth's crust as many other metals. The various REEs have many uses and applications on modern industry. For instance, Cerium Oxide is used as a polishing agent for manufacture of lenses, Europium in used in phosphors, and Lanthanum in high index-of-refraction glasses. The two most important emerging uses are the use of Neodymium, Praseodymium, Terbium and Dysprosium in the manufacture of powerful permanent magnets for use in hard drives, electric vehicles and wind turbines, and Cerium, Lanthanum and Neodymium as additives in batteries used in electric vehicles. REEs can be divided into the Light REEs (LREEs) and Heavy REEs (HREEs), with the HREEs having higher atomic numbers of 62 and higher. In the Earth's crust, and in most deposits, HREEs are relatively less abundant than LREEs.

Traditionally, REEs have been produced from minerals such as Monazite ($(Ce,La,Th)PO_4$), Loparite ($(Ce,Na,Ca)(Ti,Nb)O_3$) and Baestnäsite ($(Ce, La)CO_3F$), associated with pegmatites and carbonatites, as well as tin-bearing fold-belt granites, and are also found in associated placer deposits. While REEs are not themselves radioactive (except for Promethium, which has no stable isotopes and is therefore not found in the Earth's crust except in vanishingly small quantities), they are found together with Thorium and Uranium. As such, processing of such ores results in the production of low-level radioactive waste. In 1982, REE refining from heavy mineral concentrates left over from tin mining activities at Bukit Merah in Perak resulted in a law suit leading to the closure of the factory involved for this reason. The LINAS REE-ore processing plant, which was set up to process ore sourced from Australia, ran into similar problems due to concerns about radioactive waste.

REEs can also be found adsorbed onto particles of clay (ion-adsortion clays, IAC). Deposits of REE-bearing IACs are the result of supergene (near-surface) enrichment in lateritic weathering of rocks containing REE-bearing minerals. Intense weathering of granitic rocks under tropical conditions breaks down minerals such as feldspars into clays, as well as completely disintegrating REE-bearing minerals. The REE ions thus released become adsorbed onto the surfaces of clays, as well as Al and Fe oxides and hydroxides. Large deposits of this type have been exploited in Southern China, and more recently, in Myanmar. These deposits occur near the earth's surface, are enriched in HREEs and contain very little, if any, U and Th. The metals can be extracted by in-situ leaching, without disturbing the surface.

The keynote speaker, Dato' Sia Hok Kiang, presented a comprehensive overview of IAC REE deposits in Malaysia, and the economic prospects they offer. Parts of southern China have bedrock geology similar to parts of the Peninsula, with tin-bearing fold-belt granites. Exploration is currently in the early stages – the most promising areas are in the Western Belt, underlain by S-type granites, covered by deep weathering zones. Much of this area is under primary and secondary forest, as well as rubber and oil-palm cultivation. To avoid the negative connotations caused by the production of radioactive waste from other types of REE deposits, the term "NR-REE" (Non-Radioactive REE) was coined by JMG. Other possible exploration targets for NR-REE deposits are areas with *terra rosa* soils developed on top of limestones, areas where bauxites are found, and areas underlain with ultabasic rocks (for Sc).

A pilot project is currently in operation. In-situ extraction of REEs is conducted by pumping a solution of ammonium sulfate ($(NH_4)_2SO_4$) into injection wells at the crest of a slope. The ammonium sulfate solution percolates through the weathered zone due to gravity, and is pumped out at the foot of the slope through another series of wells. Ammonium ions displace the REE ions absorbed onto the clays. The pregnant solution is pumped into tanks, where oxalic acid or ammonium bicarbonate is added to precipitate REE salts. This process is 60-90% efficient in removing REEs from the clays. In China and Myanmar, very large precipitation pits were necessary due to the slow rate of precipitation of REE salts, however, technology exists to increase the rate of nucleation and precipitation, allowing the use of small, portable tanks.

Ammonium sulfate, in small concentrations, is not toxic to plants, and is, in fact, a fertilizer, being a source of nitrogen. After displacing adsorbed REE ions from the clay surfaces, ammonium ions in turn become adsorbed onto the clays. To avoid groundwater contamination, prior to the injection of the ammonium sulfate solution, the water table is lowered by pumping from several extraction wells. In addition, after REE extraction is accomplished, water is pumped into the injection wells to flush out excess ammonium sulfate from the weathered zone. The ammonium ion remaining on the clay surfaces will become available to the vegetation growing on the slope. The pilot project is located on an operating rubber plantation; the rubber trees are being tapped as the REEs are being extracted.

Environmental concerns were discussed. Contamination of soil and groundwater with excess ammonium sulfate, and the effects of high concentration was one. Another was the presence of large precipitation tanks or ponds – in China, and especially in Myanmar, where such pits were left abandoned and not filled in, was another. These pits are large enough to be hazards to wildlife, domestic animals and humans. The need for a comprehensive framework of regulations, and the enforcement to back it up, was discussed – in the recent past, Malaysia has had bad experiences with REE mining and processing, was well as the problems caused by bauxite mining and export, exacerbated by bad perceptions among the public, mainly caused by the activities of rogue and illegal miners. NR-REE leaching is comparatively low-impact and friendlier to the environment – it can be carried out without the need for land clearing or excavation, and needs little installed infrastructure. However, it does need to be closely monitored and proper standards and regulations formulated. Illegal and unauthorized activities need to be prevented, since it would only take one or two bad incidents to destroy its reputation among the public and the media.

The present is a good time to be developing a REE sector. The mitigation of climate change demands a reduction in the use of fossil fuels, and the massive increase in the use of electric vehicles and sources of renewable energy, both of which require large quantities of REE. In particular, there will be a sharp increase in the use of NdFeB permanent magnets. The typical EV requires 1-2kg of magnets, a wind turbine 1-3 metric tons. Developing the ability to manufacture REE-based materials would add tremendous value compared to exporting REE metals and oxides. The People's Republic of China is, at this time, the largest producer and exporter of REEs as well as NdFeB magnets. Since 2009, the PRC has been reducing export quotas of REE oxides. Recent developments in geopolitics may cause shortages and export embargoes, prompting some countries to stockpile REEs, a worldwide increase in prospecting, the opening of new mines and the 2018 reactivation of the Mountain Pass Mine in the US, which was closed in 2002 due to environmental restrictions.

The development of NR-REE mining and manufacturing of REE-related materials will provide many research opportunities for local Universities, in disparate fields. While the geology of Malaysia and Southern China may be similar, the climate is not – Malaysia experiences heavier annual temperatures and rainfall, and the techniques used to extract REEs must be adapted to local conditions. Much of this activity will take place on landslide-prone hillslopes. The use of geophysical methods to search for and develop deposits may be explored. Biologists may investigate the effect of NR-REE leaching on the local biota, and develop optimal methods to minimize environmental impacts. There are also many opportunities for material scientists and physicists to develop new REE-based products and improve existing ones, not to mention the development of new applications.

Prepared by:
Nur Iskandar Taib

For further reading:

Voßenkaul, D., Stoltz, N.B., Meyer, F.M., Friedrich, B., 2015. Extraction of Rare Earth Elements from non-Chinese Ion Adsorption Clays. Proceedings of EMC 2015, Dresden. http://www.metallurgie.rwth-aachen.de/new/images/pages/publikationen/vo_enkaeul_extr_id_8872.pdf. Accessed 19-8-2022.

Shanghai Metals Market (SMM), 2022. "Latest Update in the China Rare Earth Metals Market." https://www.metal.com/Rare-Earth-Metals/

University of Malaya American Association of Petroleum Geologists Student Chapter (UM AAPG Student Chapter) Report

2022/2023 SESSION

Field trip to Perlis

During the last two weeks before the semester break ended, AAPG University Malaya Student Chapter had successfully organised a field trip to Perlis specially for the fourth-year students since they were unable to experience physical field work in their second year in the midst of pandemic. This field trip was attended by a total of 16 students and supervised by two lecturers, Professor Madya Dr. Meor Hakif bin Amir Hassan and Dr. Nur Iskandar Taib. Both lecturers assisted the students thoroughly by providing information and a number of discussions along the way.

The study areas covered were Gunung Keriang, Bukit Tungku Lembu/Chondong and Taman Bandar Sejahtera. The participants started to gather at the department on October 7 early in the morning and left for Perlis at 8.00 a.m.. They finally reached the first study area around 5.00 p.m. before checking in the homestay/hotel. Upon arriving, the students were explained briefly regarding the outcrop, which was carbonate formation. Day 1 was leisure, only observation was mostly done by the participants.

Moving onto the second day, the study area was Bukit Tungku Lembu in Beseri district. As usual, it started with a quick briefing and brainstorming session and then printed sedimentary logging papers were distributed among us students to work on the analysis of the study area. The third day started with checking out of the stays followed by resuming to the final stop, Pokok Sena and then headed back to the campus. Throughout this trip, the students were assigned to describe, map, sketch and for some locations, they needed to prepare sedimentary logging of the outcrops and submitted everything right after. As for the sedimentary logging part, they were divided into two groups to work on the reconnaissance, texture, sedimentary structures and came out with palaeocurrents and rose diagrams.

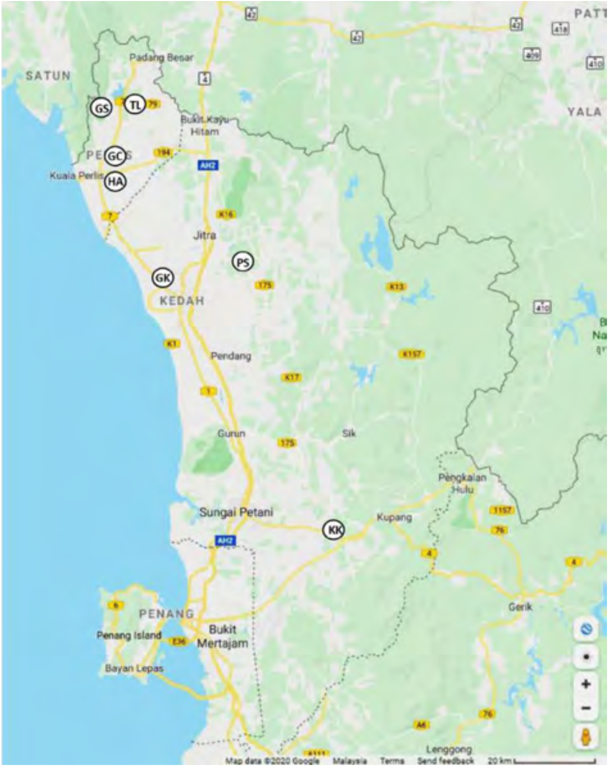


Figure 1: Outcrop location map, Perlis and Kedah. GC= Taman Rekreasi Gua Cenderawasih; GK= Gunung Keriang; GS= Guar Sanai, HA= Hutan Aji; PS= Pokok Sena; TL= Bukit Tungku Lembu.

Figure 2: Outcrop Location Map, Pokok Sena. BL= Tapak Geowarisan Bukit Larek; BS= Taman Bandar Sejahtera; PC= Taman Puncak Sena.

To sum up, this field trip has helped them in some ways such as equipping themselves with the knowledge of geological mapping of study areas. Not only they managed to grasp the theories and concepts of using geological equipment, with this a bigger picture of being a geologist and hands-on situations had been experienced. Also, this whole trip was hoped for them to have a better understanding of the lithology and stratigraphy history of each specific areas. Hence, the event is considered a success since the objectives were achieved which also proved that exposure to such actual fieldwork increases the students' knowledge for the industries and helped them have a better understanding of what was taught in class.

Figure 3 and Figure 4: Carbonate formations; pictures of Gunung Keriang (1st stop).

Figure 5 and Figure 6: Measuring the strike and dip of the outcrop.

Figure 7: Group photo of lecturers and participants.

Prepared by:
Nur Farhana Binti Mohd Sazlee,
Secretary, UMSC AAPG

University of Malaya Geological Society of Malaysia Student Chapter (UM GSM Student Chapter) Report

2022/2023 SESSION

Geology Interaction Day 2022

Geology Interaction Day 2022 (GID) merupakan program tahunan yang telah diadakan pada 16 Oktober 2022 bertempat di Dewan Kuliah Geologi, Jabatan Geologi, Universiti Malaya. Program ini dikendalikan di bawah anjuran Universiti of Malaya Geological Society of Malaysia Student Chapter (UM GSM SC) dengan tujuan mengalu-alukan pelajar tahun 1 Geologi Gunaan ke Universiti Malaya dan Jabatan Geologi. Geology Interaction Day 2022 mendedahkan pelajar tahun 1 Geologi kepada tenaga pengajar, peluang biasiswa, kelab dan persatuan serta peluang pekerjaan. Seramai 44 orang peserta yang merupakan pelajar tahun 1 Geologi telah menyertai program ini.

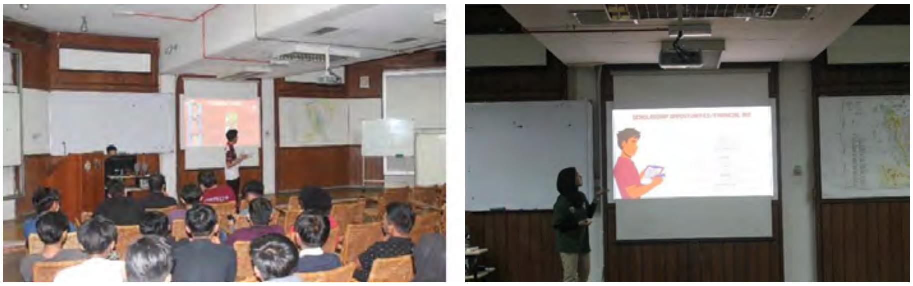
Aturcara program ini bermula dengan Majlis Perasmian pada pukul 9.00 pagi, diikuti oleh sesi Ice Breaking . Seterusnya adalah Sharing Session 1 dimana peserta dapat mengenali barisan pensyarah dan kakitangan di Jabatan Geologi. Mereka juga didedahkan kepada kelab dan persatuan yang mereka boleh sertai. Sejurus itu, para perserta memasuki sesi rehat. Selepas itu berlangsung Sharing Session 2 di mana peserta didedahkan kepada peluang biasiswa, peluang pekerjaan dan juga acara yang akan datang . Akhir sekali adalah sesi pemilihan 1st year batch representative pada pukul 2.00 ptg. Berikut disertakan beberapa gambar aktiviti yang telah dijalankan semasa program berlangsung.

Kesimpulan yang dapat dibuat adalah dengan pendedahan yang mencukupi, pelajar tahun 1 Geologi Gunaan mampu merancang masa depan mereka dengan lebih efektif dalam menghadapi pelbagai jenis cabaran yang bakal ditempuhi sepanjang pengajian mereka di alam universiti ini. Pihak penganjur juga berharap dengan pendedahan terhadap kelab dan persatuan yang disediakan sedikit banyak dapat menyemarakkan minat mereka untuk menyertai kelab dan persatuan tersebut supaya mereka boleh memperoleh serta memperkuatkan lagi kemahiran insaniah yang mana merupakan kemahiran yang penting dalam dunia pekerjaan kelak.

Laporan disediakan oleh :
Nopporn Khongphakdee
Pengarah Geology Interaction Day 2022

Gambar 1: Foto menunjukkan peserta memasuki Dewan Kuliah Geologi.

Gambar 2: Majlis perasmian program Geology Interaction Day 2022.



Gambar 3: Sesi pengenalan pensayarah-pensyarah di Jabatan Geologi dan pendedahan terhadap peluang biasiswa.

Gambar 4: Wakil daripada setiap kelab mempromosi kelab masing-masing.

Gambar 5: Menunjukkan sesi pemilihan 1st year representative.

Gambar 6: Sesi bergambar peserta, jurubicara dan ahli jawatankuasa Geology Interaction Day 2022.

GSM-UMS Geology Club programs held in November 2022

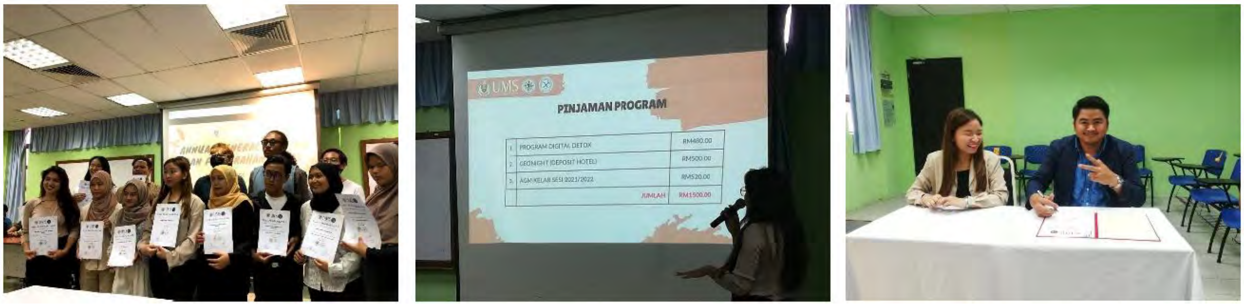
KOTA KINABALU – On November 7, 2022, the GSM-UMS Geology Club has organized a hybrid seminar, entitled 'ITB-UMS Postgraduate Seminar' that took place in Lecture Room 4, Faculty of Science of Natural Resources, Universiti Malaysia Sabah. This programme was participated by the geology students of Universiti Malaysia Sabah (UMS) and Institusi Teknologi Bandung (ITB). Two postgraduate students from UMS and three postgraduate students from ITB were invited as speakers of the programme to share about their postgraduate research and studies. This programme is held to expose current undergraduate students about postgraduate studies and some current geological studies.

In addition, GSM-UMS Geology Club has also hosted an Annual General Meeting and Handover Ceremony of 2021/2022 Session on 11 November, 2022 that took place in Lecture Room 3, Faculty of Science and Natural Resources, Universiti Malaysia Sabah. This programme was held to present the annual activity and financial report to club members as well as to show appreciation to the outgoing committees. This programme was attended by 126 geology students from Year 1 to 4 and three lecturers. GSM-UMS geology club was also honoured to be able to invite the Vice President of Geological Society Malaysia (GSM), Prof. Madya Ts. Dr. Mohd Hariri bin Ariffin to share about the membership system of GSM.

Lastly, all of the programmes were carried out smoothly, with positive feedback from the participants. We truly want to host more interactive and beneficial geology-related programmes in the future in conjunction with GSM and GSM-UMS Geology Club. Thank you very much.

Wong Yee Huey,
Secretary GSM-UMS Geology Club 2022/2023 Session
December 2022

Pictures of the programme on November 7, 2022. Photo by: Publicity Unit of GSM-UMS Geology Club.



Photographs taken during Annual General Meeting. Photo by: Publicity Unit of GSM-UMS Geology Club.

UPCOMING EVENTS

February 1-3, 2023: NAPE Summit 2023, Houston, Texas. Please visit https://napeexpo.com/summit for further information.

February 7-9, 2023: (Virtual) Geothermal-CCS-Hydrocarbon Crossover Workshop; 8:00 a.m.–5:00 p.m.; Virtual Workshop via Zoom (London, England time). Please visit AAPG Event Listings page (https://www.aapg.org/events/event-listings) to learn more about the workshop.

February 8-9, 2023: Caribbean Geosciences Technology Workshop; Barranquilla, Colombia. Please visit AAPG Event Listings page at https://www.aapg.org/events/event-listings to learn more about the workshop.

February 19-21, 2023: Middle East Oil, Gas and Geosciences Show (MEOS GEO); Exhibition World Bahrain. Check out https://meos-geo.com/visit/about-the-show/ for further details, or contact the conference organiser for conference queries (Olga Vyshnevska, Email: ovyshnevska@spe.org).

February 21-23, 2023: AAPG/EAGE Papua New Guinea Petroleum Conference and Exhibition; Port Moresby, Papua New Guinea. For further information, please contact Mahenoor Malik (AAPG) via email mmalik@aapg.org.

March 1-3, 2023: International Petroleum Technology Conference (IPTC); Bangkok, Thailand. Visit website for further details: https://iptcnet.org/.

March 6-9, 2023: Asia Pacific Meeting on Near Surface Geoscience and Engineering (NSGE); Taipei, Taiwan. Further details are available at: https://eage.eventsair.com/5th-asia-pacific-meeting-on-near-surface-geoscience-engineering/.

March 13-18, 2023: Australasian Exploration Geoscience Conference 2023. Contact aegc@arinex.com.au for general enquiries, or visit https://2023.aegc.com.au/ for further information regarding the event.

March 15-16, 2023: Geo Connect Asia Show & Conferences; Marina Bay Sands, Singapore. Visit https://www.geoconnectasia.com/ to learn more about the event which aim to provide geospatial & location intelligence solutions.

March 22-23, 2023: Energy Opportunities 2023 Conference; Camino Real Polanco, Mexico City. Further details are available at https://energyopportunities.info/2023/.

April 23-28, 2023: European Geosciences Union (EGU) General Assembly 2023; Vienna, Austria. Visit event website, https://www.egu23.eu/ for further details.

May 1-4, 2023: Offshore Technology Conference; Houston, Texas. Further details can be found at: https://2023.otcnet.org/welcome.

May 24-27, 2023: 14th International Symposium on Pseudokarst; Sudetes, Poland. Visit website: https://14pseudokarst.wonders4you.com/ for more information.

June 13-15, 2023: Unconventional Resources Technology Conference (URTeC); Denver, Colorado. Further details can be obtained at: https://urtec.org/2023/.

September 4-6, 2023: APPEC 2023 (39th Annual Asia Pacific Petroleum Conference); Singapore. Website: https://plattsinfo.spglobal.com/appec2023.html.

October 9-11, 2023: World Geothermal Congress 2023; Beijing, China. Please visit www.wgc2023.com to learn more about the event.

Geological Society of Malaysia Publications

Instruction to Authors

General Policy

Papers should be as concise as possible. They may include original results of basic, applied and policy research of national or international significance, current reviews, or discussions on techniques, research programs, organisations, information, or national and international policies in geoscience.

Submission of Papers

Only papers that have not been published elsewhere (except those in the form of abstracts, published lectures or academic theses), including electronically, will be considered for publication. Authors must agree not to publish elsewhere the submitted or accepted articles in the same form, in English, Malay or other languages. Originality detection services may be used to check your manuscript to verify its originality.

All papers will be subjected to review by two or more reviewers. Authors wishing to include published and unmodified figures or text passages are required to obtain permission from the copyright owner(s). Authors of English papers are strongly urged to have their manuscript edited for language before submission by a person whose first language is English.

The Editor reserves the right to reject all or any part of the paper submitted. The Geological Society of Malaysia assumes no responsibility for statements made by authors.

The paper should be submitted to:

The Editor,
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

Manuscript

The paper can be written in Bahasa Malaysia (Malay) or English. For English papers, use either British or American spelling but not a combination of both. The paper should be checked thoroughly for spelling and grammar. The manuscript must be printed at 1.5 spacing in a single column on one side of A4 paper. All pages should be numbered. Length of paper should be between 3,000 and 8,000 words for the Bulletin and between 2,000 and 3,000 words for Warta Geologi, excluding tables and illustrations. Metric units should be used and all non-standard symbols, abbreviations and acronyms must be defined.

Title

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.

Abstract

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

Keywords

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

References

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.

The list of references should only include articles cited in the text. The list should be arranged in alphabetical order. Please ensure that the reference list is complete and the bibliographical details are accurate. The references should be in the following manner:

Journal article:

Suntharalingam, T., 1968. Upper Palaeozoic stratigraphy of the area west of Kampar, Perak. Geol. Soc. Malaysia Bull., 1, 1-15.

Book:

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

Chapter of book and Symposium volume:

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

Article in Malay:

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

Tables

All tables should be cited in the text and numbered consecutively. Tables should have a title and a legend explaining any abbreviation or symbol used. Each table must be printed on a separate piece of paper. Do not insert the tables within the text. Data in tables should be aligned using tab stops rather than spaces. Avoid excessive tabulation of data.

Illustrations

Please make sure that all illustrations are useful, necessary and of good quality. A maximum of ten (10) illustrations (photographs, graphs and diagrams) are allowed and these should be cited in the text and numbered consecutively as Figures. The papers are usually published in black-and-white but it may sometimes be possible to include colour figures at the author's expense. The scales for maps and photomicrographs should be drawn on the figure and not given as a magnification. Originals should not be greater than A4 size and annotations should be capable of being reduced down to 50 percent. The caption should be listed on a separate piece of paper. Do not insert the illustration within the text.

Submission of Electronic Files

Authors are required to submit electronic files in a CD-ROM or email as attachments. The submission should be accompanied with a listing of all files and the software (name and version) used. The file names should reflect the content of the files (e.g. Ali_Fig1.tif). Please make sure that the files and the hardcopies are the same.

Preferred Software

Text: Microsoft Word. Do not insert tables and illustration within the text.

Tables: Microsoft Word or Microsoft Excel. Please submit as separate files.

Illustrations – Vector Graphics: Adobe Illustrator (preferred), CorelDraw and Freehand. Final line thickness should be at least 0.5 point or 0.17 mm. For other software, please submit one copy in the native file format and export one copy as a PDF file with all fonts embedded and one copy as a high resolution TIFF or JPEG image.

Photographs or bitmap (raster) images: Adobe Photoshop. Please save as TIFF or PSD files. Save/scan line art at 600 to 1200 dpi and greyscale figures at 300 to 600 dpi. High resolution JPEG, TIFF or GIF files from other sources are also acceptable. The resolution must be high enough for printing at 300 dpi.

PP2509/07/2013(032786) ISSN 0126-5539; e-ISSN 2682-7549

WARTA GEOLOGI PERSATUAN GEOLOGI MALAYSIA

Jilid 48, No. 3 • Volume 48, No. 3 • December 2022

KANDUNGAN (CONTENTS)

Published by the GEOLOGICAL SOCIETY OF MALAYSIA
Department of Geology, University of Malaya, 50603 Kuala Lumpur, MALAYSIA
Tel: 603-7957 7036 Fax: 603-7956 3900 E-mail: geologicalsociety@gmail.com

Printed by Nets Printwork Sdn. Bhd., No. 56, Jalan PBS 14/4,
Taman Perindustrian Bukit Serdang, 43300 Seri Kembangan, Selangor