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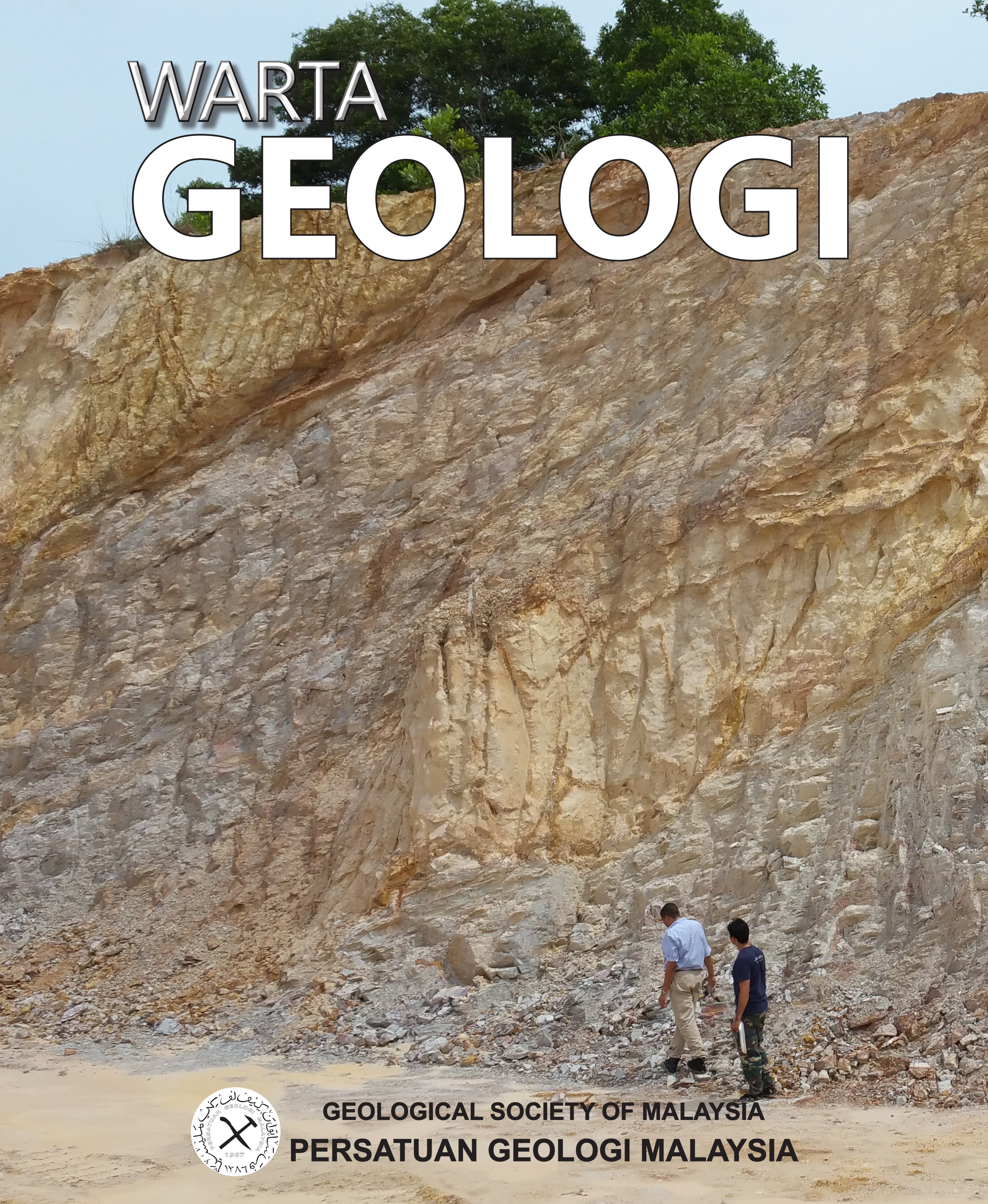

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Cover photo: Interbedded sandstone and mudstone of Kenny Hill Formation at Bandar Baru Salak Tinggi, Selangor. Photo by: Dr. Mohd Hariri Arifin

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The thermal stability and morphological study of weathered and intact limestone

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Abstract: Limestone, a multifunctional sedimentary rock, operates as an important component in several scientific and economic sectors. Its versatility and diverse application underline the significance of completely knowing its morphology and thermal stability to enhance consumption and ensure optimal preservation. The aims of this paper are to understand how variations in microstructural characteristics impact thermal conductivity and heat transmission parameters, thereby uncovering fundamental mechanisms governing limestone's response to heat stress. Thus, the objectives of study are to investigate and analyze intact and weathered limestone rocks in terms of thermal stability (i.e.: temperature effects on limestone›s stability and weight) and morphology (i.e.: differences in surface morphology, porosity distribution, and microstructural features) using advanced techniques like Thermogravimetric Analysis (TGA) and Scanning Electron Microscopy (SEM), respectively. From the thermal stability analysis, it revealed that weathered limestone showed the maximum peak weight loss of 4.54% per minute at 778.31°C, whereas intact limestone showed the highest weight decrease rate of 3.2% per minute at 734.45°C. It can be summarised that weathered limestone demonstrates a more intricate and rapid thermal deterioration profile in comparison to intact limestone. The morphology analysist revealed the different particle size distributions; weathered limestone had long, deep fractures with a distribution from 1.89μm to 31.0μm, while intact limestone showed a range from 1.39μm to 14.0μm. The presence of uneven shapes and a range of sizes of particles is indicative of the weathering and erosion processes that cause the limestone structure to break apart and disintegrate. The identified patterns and trends for each different limestone conditions explained the complex relationship between morphology and thermal stability that improve decision-making processes in multiple fields. In conclusion, it is important knowing limestone's morphology and thermal behavior to optimize consumption and assure good preservation. The findings have practical ramifications that go beyond theoretical comprehension, providing useful information for preservation and implementation in a variety of sectors and domains.

Keywords: Intact, limestone, morphological, thermal, weathered

INTRODUCTION

Limestone, a ubiquitous sedimentary rock, holds crucial relevance throughout geological, industrial, and architectural domains due to its abundance and unique qualities. Composed mostly of calcium carbonate ($CaCO_3$) with various impurities and secondary minerals; limestone undergoes continual alteration processes throughout its geological history, resulting in the production of both intact and weathered varieties (Müller, 2021). Intact limestone indicates the pristine state of the rock, keeping its original mineralogical and structural integrity. Conversely, weathered limestone experiences variations due to external forces such as weathering, erosion, and chemical reactions, resulting to changes in its physical and chemical properties (Hack, 2019). Understanding the delicate relationship between the morphology and thermal characteristics of limestone is vital for different scientific and practical applications. The morphology of limestone, including pore structure, grain size, and surface topography; directly determines its thermal performance. Changes

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in morphology generated by weathering processes can considerably alter the rock's thermal stability and heat transmission capabilities (Hashim, 2022).

Previous research has extensively examined the thermal behaviour and morphological evolution of limestone in varied settings. However, gaps in understanding continue, notably regarding the intricate interplay between shape and thermal stability in weathered and intact limestone (Jodry *et al*., 2023). This study intends to solve these gaps through a comprehensive comparative analysis of the thermal stability and morphology of weathered and intact limestone. Leveraging modern techniques such as Thermal Gravimetric Analysis (TGA) and Scanning Electron Microscopy (SEM), in order to explore the fundamental distinctions between these two versions and uncover the underlying mechanisms driving their thermal behaviour.

Limestone formation

Limestones are rocks that contain more than 50% carbonate minerals, at least 50% of which are aragonite or calcite. The colours of limestone range from white to grey to dark grey to yellow, green, blue, and occasionally even black (Silva *et al*., 2022). A mixture of clayey material, glauconite, or finely dispersed ferrous compounds causes a greenish tint, while the presence of ferric iron causes a reddish or brownish coloration (Müller, 2021). Compared to fine-grained limestones, which are typically indicative of deeper, potentially decreasing circumstances during early diagenesis, coarse-grained limestones typically exhibit lighter colours, which are linked with well-oxidized environments. Magnesium carbonates, dolomite, silica, glauconite, gypsum, fluorite, siderite, sulphides, iron and manganese oxides, phosphates, clays, and organic materials are among the several impurities found in limestone (Rajendran & Nasir, 2014).

Calcareous sandstone, shale and others are defined as having a $CaCO_3$ content of slightly less than 50%. Differential weathering frequently occurs in its carbonate portion, giving it the appearance of limestone. Insoluble quartz grains and other materials are typically inconspicuous and readily released during weathering processes. Certain calcareous aeolianites that contain less than 30% $CaCO_3$ go on to form karst landforms and other limestone characteristics. The majority of sedimentary carbonate rocks are the result of deposition in marine environments, with paralia and autogeosynclines serving as the main repository in neritic settings. Although it is not as common as that of banks, platforms, and shelves, calcium carbonate can also build up in deep water and in coral atoll structures encircled by an abyssal zone. The primary material that makes up limestone is the calcium carbonate ($CaCO_3$) mineral calcite. Modern seas contain large amounts of calcium carbonate in its dissolved state, but certain requirements must be satisfied for the mineral to precipitate as a solid (Silva *et al*., 2022). The primary biological process used to precipitate calcite from seawater. Calcite is used by a variety of marine creatures to form their shells and skeletons, which, when they die, fall to the seafloor, where they are buried and compacted into sedimentary rock. The bone pieces and grains may never make it to the seafloor, though, as calcite dissolves readily. Furthermore, the environments in which those marine species live regulate the deposition of limestone in particular geographical areas. Because limestone formation is restricted, its presence or absence in the geologic record provides information about the climate and geographic circumstances of the era (Kambakhsh *et al.*, 2024).

Batu Caves geological formation

The Batu Caves is a geographically distinct limestone hill, characterized by its dome shape, situated at coordinates 3.2379° N and 101.6840° E, with an elevation of roughly 390 meters above sea level. It is positioned around 11 kilometers northeast of Kuala Lumpur, as documented (Kiew & Rahman, 2021). The geological composition of the Batu Caves mostly consists of Silurian limestone, a rock formation dating back about 400 million years to the Paleozoic epoch. Following the initial deposition of the rock, it underwent a series of geological transformations, including uplift, compression, heating, and folding, which took place millions of years later during the Triassic period, approximately 200 million years ago. However, it is plausible that these processes commenced as early as the Devonian-Carboniferous period, around 300 million years ago. The majority of the limestone underwent a transformation into crystalline marble and then underwent uplift, resulting in the formation of the mountain ranges (Zabidi & Freitas, 2006). The limestone formation of Batu Caves exemplifies the intricate connections between geological processes and the passage of time. The place exhibits the exceptional artistic abilities of nature, featuring visually striking stalactites, stalagmites, and intriguing formations within the cave (Dodge-wan, 2015). Every curve, contour, and crack present in the limestone is a testament to the ancient history of the Earth, intricately imprinted inside the very structure of the cave. Limestone is a sedimentary rock composed of calcite minerals, chemically known as calcium carbonate ($CaCO_3$). Dolomite [Ca Mg (CO_3)] is another prevalent mineral found in limestone (Chowdhury *et al*., 1990). Frequently encountered impurities inside limestone are characterized by its microcrystalline, cryptocrystalline quartz, amorphous silica composition (SiO_2), clay, organic debris, and iron oxides. Limestone exhibits a distinctive characteristic as it possesses solubility even in mildly acidic aqueous environments, including carbonic acid from dissolving carbon dioxide in water (Tan, 2002).

The Batu Caves area located in Gombak District is shown in the geological map (Figure 1). The map showcases a complex interplay of sedimentary, metamorphic, and intrusive rock formations, centred around the renowned Batu Caves. The region features isolated continental basin deposits from the Late Tertiary period, composed of shale, sandstone, and conglomerate, which reveal the remnants of ancient sedimentary basins. Metamorphic formations, including schist, phyllite, slate, and limestone intercalations, dominate parts of the district, shaped by immense geological pressures and transformations over time.

Marine and continental deposits, consisting of clay, silt, sand, and gravel, highlight the influence of past marine and riverine processes. Pink zones represent acid intrusive rocks, remnants of magmatic activity near the area, while yellow zones of vein quartz indicate areas of mineral concentration formed by ancient fluid movements. Scattered water bodies, marked in blue, add ecological significance and diversity to the terrain.

Batu Caves, nestled within limestone formations, exemplifies the region's karstic landscape, blending natural history with cultural heritage. This map provides an understanding of Gombak's geological framework, showcasing its evolution and the dynamic processes that have shaped its iconic features. The Kenny Hill Formation, a younger sequence of metasedimentary rocks is composed of phyllite and quartzite and situated on top of the Silurian Kuala Lumpur Limestone. The Hawthornden Schist Formation is made up of fine-grained pyrite-bearing graphitic schists that have a dark color. The oldest rock formation in Kuala Lumpur is the Dinding Schist, which is Cambrian to Ordovician in age and is composed of schistosed conglomerate, calc-silicate and quartz-mica schists (Gobbett, 1965).

Weathered limestone grade in Batu Caves

The weathering of limestone in Batu Caves is a complex process influenced by various factors, including environmental conditions, rock properties, and the duration of exposure to weathering. These caves, located in Selangor, Malaysia, are a significant geological and cultural site, showcasing the interplay between natural weathering processes and human activity. Understanding the grade of weathered limestone in Batu Caves requires examining the specific mechanisms of physical, chemical, and biological weathering that affect this unique limestone formation.

a) Physical weathering

Physical weathering, also known as mechanical weathering, involves the breakdown of rocks without chemical alteration (Camuffo, 1995). In Batu Caves, this process is primarily driven by temperature fluctuations and water infiltration. Weathering in Batu Caves is not only driven by natural processes but also significantly influenced by human activities. Thousands of visitors frequent the site annually, engaging in various activities that contribute to the physical deterioration of the limestone. Additionally, fog plays a role in physical weathering by promoting moisture accumulation on the

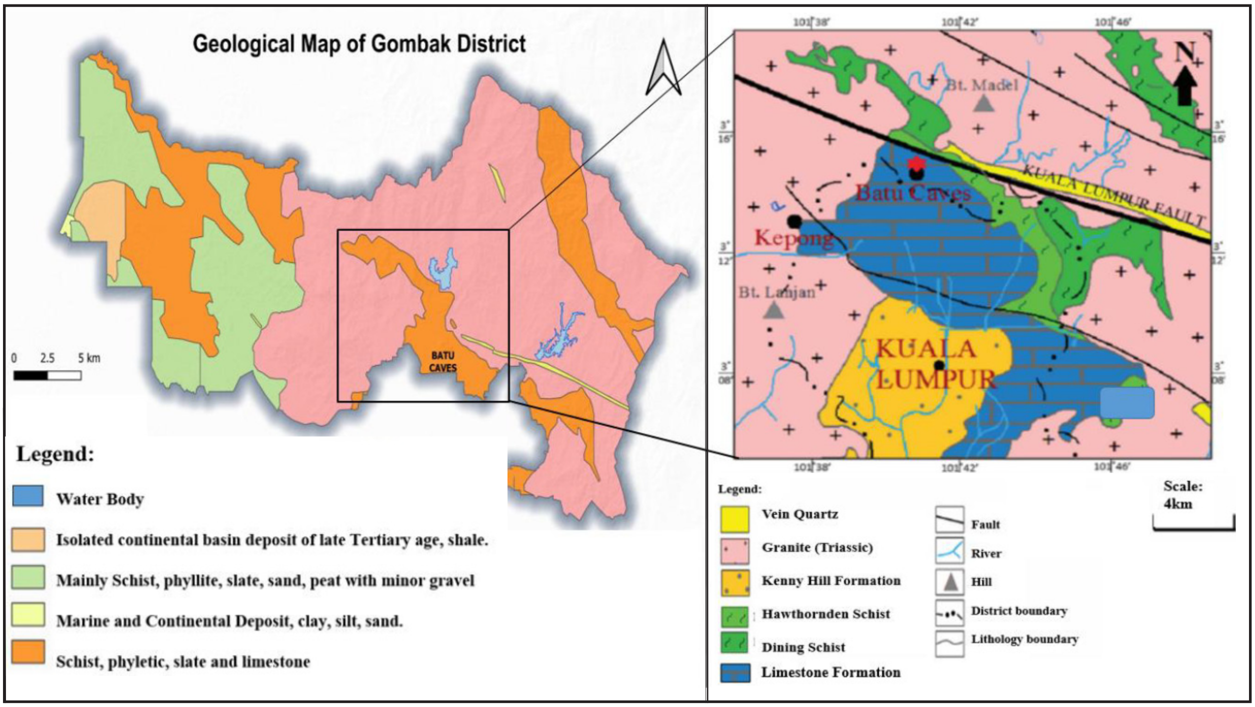

Figure 1: Geological Map of Batu Caves, Gombak, Selangor. (source: Added and modified from Goh *et al*., 2018).

Figure 2: The photos showing the type of weathering limestone (a) physical (b) chemical and (c) biological weathering limestone in Batu Caves, Malaysia.

rock surfaces, leading to increased erosion and mechanical breakdown. This impact of fog on physical weathering is illustrated in the accompanying Figure 2a.

b) Chemical weathering

Carbonation is a process of an atmospheric carbon dioxide (CO_2) combines with water to form carbonic acid (H_2CO_3) (Price & Velbel, 2003). This reaction leads to the gradual weakening and dissolution of limestone, contributing to the formation of karst landscapes, characterized by features such as caves, sinkholes, and limestone pavements. In Batu Caves, evidence of carbonation is visible in the smooth, rounded surfaces of limestone formations shown in Figure 2b.

$$CaCO_3 + H_2O + CO_2 = Ca\,(HCO_3)_2 \qquad \text{Equation (1)}$$

(Limestone + water + carbon dioxide = Calcium bicarbonate)

c) Biological weathering

Biological weathering involves the physical or chemical alteration of rocks by living organisms (Bland & Rolls, 2020). In Batu Caves, plant roots and microorganisms play a significant role in the weathering process. Plant roots can grow into fissures and crevices in limestone, exerting pressure as they expand over time, roots can cause significant physical damage to the rock, leading to its fragmentation and weakening. In the context of Batu Caves, the presence of vegetation contributes to the degradation of limestone structures. As plants mature, their roots penetrate deeper into the rock, exacerbating the weathering process shown in Figure 2c (Dontsova *et al*., 2020).

Weathering processes and impact on limestone

The process of weathering limestone entails the gradual disintegration and modification of its minerals and structure over a period of time. This process can be affected by a range of elements, such as climate, biological activity, and environmental circumstances (Benavente *et al*., 2021). Physical weathering, such as the repeated freezing and thawing of water and the wearing down of rock surfaces, can cause the formation of cracks and the enlargement of pore spaces in the rock. Chemical weathering, which occurs through reactions with acidic rainwater or atmospheric gases, can result in the dissolution of calcite and the subsequent creation of secondary minerals such as gypsum (Kambakhsh & Nik Norsyahariati, 2023). Organisms such as lichens and bacteria can speed up the deterioration process by producing organic acids and other byproducts through biological weathering. The parameters that play a role in the weathering mechanism of limestone are shown in Table 1.

Limestone morphological and thermal stability

Understanding limestone's morphology and thermal stability is critical to many fields, including engineering, geology, and materials science. Sedimentary rocks like limestone are commonplace and are used extensively in

Table 1: Various parameters cause weathering of limestone formation (Dans & Royaume, 1974).

Environmental Factors	Time Year	Rock Properties	Response
Temperature	Varying	Mineralogical composition	Discoloration
Moisture	Geological time	Fabric and grain structure	Decomposition
Chemical fluids	Different	Structural defects	Disintegration

construction, geological research, and industrial processes. Its structural characteristics and thermal behaviour significantly impact how well-suited it is for different uses and how it reacts to external stimuli (Beyer & Mrozek, 2022).

Morphology refers to the structural features of limestone, such as pore size distribution, texture, and crystal orientation. Scanning Electron Microscopy (SEM) is a potent method for analysing morphology, providing high-resolution imaging that is crucial for identifying microstructural characteristics (Zeng *et al*., 2017). Morphological characteristics affect the mechanical characteristics of limestone-based materials and also have a role in determining their thermal capacity, permeability, and vulnerability to weathering and damage (Noraini *et al*., 2022).

Thermal stability clarifies the temperature-dependent breakdown of limestone and is frequently assessed using methods such as Thermogravimetric analysis (TGA) (Radulović *et al*., 2017). Thermogravimetric analysis (TGA) is a valuable technique for comprehending limestone's thermal behaviour. The important insights on the material's sensitivity to temperature variations can be determined by graphing the TGA curve, which shows the rate of weight change, against temperature. Differential thermo-gravimetry (DTG) curve peaks indicate specific weight loss events and provide important insights into the underlying mechanisms and the impact of temperature on these processes. Prior TGA investigations of limestone have yielded important insights into its thermal properties and responses to temperature changes. It showed how TGA clarified key patterns of weight loss in limestone, revealing procedures like dehydration and the oxidation of organic materials to produce limestone and carbon dioxide from carbonates, particularly calcite (Li & Wang, 2022). Understanding thermal behaviour is crucial for cement production and other businesses that rely on limestone to optimize manufacturing procedures and guarantee product quality. Furthermore, thermal stability evaluations aid in the interpretation of the thermal history of historical artifacts and limestone formations in disciplines such as geology and archaeology (Niry *et al*., 2013).

These results highlight how crucial TGA is for understanding the complex thermal behaviours of limestone and how it reacts to its surroundings. The objective of this work is to gain a greater understanding of the thermal dynamics of limestone by utilizing these insights to examine the thermal stability of both intact and weathered limestone samples.

MATERIALS AND METHODOLOGY

Sample collection and preparation

Limestone rock is used as the principal material for this study. In the sample selection process, six limestone samples were retrieved; the first group consisted of three specimens of intact limestone taken from the exterior of Batu Caves, precisely pinpointed at GPS used (Brand: GARMIN, model: STAM Map 76csx), coordinates N 03°14'14.5" and E 101°40'58.4". Additionally, the second group comprised three intact limestone samples were gathered from a specific point within the cave's confines, identified by GPS coordinates N 03°14'17.7" and E 101°41'01.4", shown in Figure 3. The process of taking limestone samples according to the C-50 standard was selected from the areas that were physically deformed (ASTM, 2006).

The labelling and names of each limestone samples studied in this work are shown in Table 2 for future references in this paper.

After transferring the limestone samples to the laboratory, the preservation and identification of samples were prioritized, each sample was carefully labelled to ensure that the limestone sample remained unaltered and underwent no transformations upon arrival at the

Figure 3: The GPS locations of weathered limestone from outside Batu Caves (Location 1) and intact limestone sampling from inside (Location 2) Batu Caves.

Table 2: Labelling of limestone rock samples – intact and weathered limestone.

Samples	Labels / Names
Intact Limestone	
Sample 1	Intact – S1
Sample 2	Intact – S2
Sample 3	Intact – S3
Weathered Limestone	
Sample 1	Weathered – S1
Sample 2	Weathered – S2
Sample 3	Weathered – S3

Figure 4: The laboratory procedures in preparing the samples for characterising tests (a) limestone samples, (b) washing process and (c) drying process in the oven.

laboratory for analyses (Figure 4a). The first step to take is the washing process where the limestone samples need to be cleaned to eliminate any superficial impurities and pollutants. The process is important for ensuring that the subsequent examinations were carried out on unadulterated material (Figure 4b). Following thorough preparation, the samples underwent a finely regulated drying procedure. The procedure involved subjecting the samples to a constant temperature of 110°C for a continuous period of 24 hours. The drying method was conducted in accordance with the prescribed guidelines specified in ASTM D5731 (Conshohocken, 1995; Figure 4c).

After completing the preparing process, the limestone samples were subjected to reducing their particle size to achieve a uniform and granular state, which would aid in conducting further analyses. The reduction process entailed applying mechanical force using crushing and grinding techniques using pastel and mortar to attain a consistent distribution of particle sizes in the samples. In order to achieve a more precise particle size, the limestone samples that had been crushed and ground were meticulously placed into a sieve with a specified aperture size of 300µm. The purpose of this sieving operation was to maintain the uniformity of the particle size distribution and eliminate any data points that deviated significantly from the norm. This was done to improve the precision and reliability of the subsequent analytical methods.

Thermogravimetric analysis (TGA)

Thermogravimetric analysis (TGA) of limestone weathering provides insights into the behaviour of this material under temperature variations and provides an understanding of its durability and stability in environmental circumstances. For this study of limestone thermal stability analyses, the TGA instrumentation (Brand: Mettler Toledo) was used. It works with high accuracy at a temperature between 25°C and 1000°C using a 10°C/min heating rate. The sample was put inside the machine at a precisely regulated temperature and increased it at a consistent rate, following ASTM E2402-19 (ASTM International, 2019). As the temperature increment took place, the limestone underwent transformations, and some of its constituents began to evaporate or decompose. The effect of those modifications changed into something observed in terms of weight loss, which can be minute even though sizable.

At the same time, the particular temperature at which these adjustments occurred were monitored and recorded. This fact-series technique became important because it provided essential insights into the limestone's thermal behaviour. It allowed to pinpoint the exact temperature factors at which weight reduction came about, signifying the onset of various tactics, which include the release of unstable additives or alterations within the limestone's shape.

Scanning electron microscopy (SEM) analysis

The surface morphology of limestone was determined by employing a scanning electron microscope (SEM) with a 5k accelerating voltage (Brand: Hitachi SU3500, modes 60-650Pa). The magnification range is within the values of 1000 and 50000X for limestone as specified by ASTM C1437 (ASTM International, 2009). The analysis was carried out to examine and evaluate the fine details of the mineral composition, possible microfractures, and surface shape of the limestone. From the examination of intact and weathered limestone, the aims are to shed light on characteristics, especially due to weathering processes.

RESULTS

Thermal stability analysis – Intact limestone

The results of thermal stability analysis for intact limestone samples were presented in this section and temperature thermogram in Figure 5 will be referred. For Intact - S1 sample, the pinnacle level for weight reduction, 3.1%/min, arrived at a steady warming pace of 728.75°C (Figure 5a). Followed by Intact - S2, the TGA results show the pinnacle level for weight reduction arrived at 2.4%/

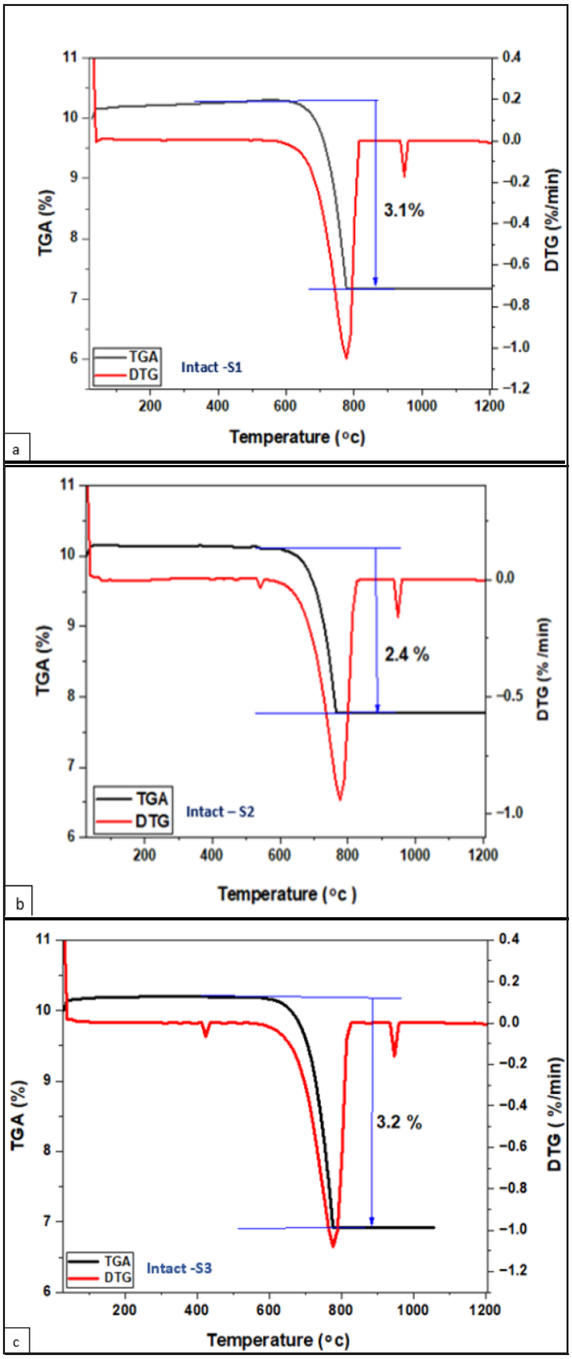

Figure 5: Thermogravimetric analysis of intact limestone samples (a) Intact – S1, (b) Intact – S2 and (c) Intact – S3.

min, happening at 772.90°C (Figure 5b). Sample Intact - S3 has shown the pinnacle level for weight reduction enrolled at 3.2%/min, happening at 734.45°C (Figure 5c).

From all the results (Table 3), it has described the warm way of behaving and disintegration profile of the subsequent limestone test, underscoring key temperature focuses and pace of weight reduction.

Thermal stability analysis – Weathered limestone

This section will present the results on thermal stability of weathered limestone while temperature thermogram will be referred as in Figure 6. The summarised values from the temperature thermogram were tabulated in Table 4.

The TGA analysis of sample Weathered-S1 show the pinnacle level for weight reduction arrived at 4.1%/min, happening at 778.47°C. This extensive figure discloses basic temperature spans and disintegration profiles, helping with the comprehension of the fourth limestone test's warm way of behaving (Figure 6a). For Weathered-S2 sample, the thermogravimetric analysis has revealed the slope variations in various regions of the thermogram (Figure 6b). The initial thermal event linked to moisture loss transpires within the temperature range of 200°C. Subsequently, a second loss reaction occurs between 300 – 650°C with a loss weight of 0.21%, which is associated with the magnesium carbonate decomposition that liberates CO_2. In a similar vein, decomposition is linked to the third thermal event; nevertheless, the substance that is dissociated is calcium carbonate, and the slope of the baseline changes occurs within the temperature range of 650 – 800°C. In the process of decomposition, both substances liberate carbon dioxide as magnesium and calcium oxides are formed. The pinnacle level for weight reduction was 4.54 %/min happening at 734.45°C. This curve gives itemized experiences into the temperature focuses and weight reduction qualities of the fifth limestone test.

Meanwhile, Weathered-S3 sample presents the initial thermal event linked to moisture loss transpires within the temperature range of 200°C (Figure 6c). Subsequently, a second loss reaction occurs between 375 – 650°C with a loss weight of 0.24%, which is associated with the magnesium carbonate decomposition that liberates CO_2. In a similar vein, decomposition is linked to the third thermal event; nevertheless, the substance that is dissociated is

Table 3: The results of the thermal analysis of samples of intact limestone.

Sample	Temperature Range (°C)	Weight Loss (%/min)	Peak Temperature (°C)
Intact – S1	27.40 -145.12	3.1	728.75
Intact – S2	28.42 -142.59	2.4	772.90
Intact – S3	27.18 -147.88	3.2	734.45

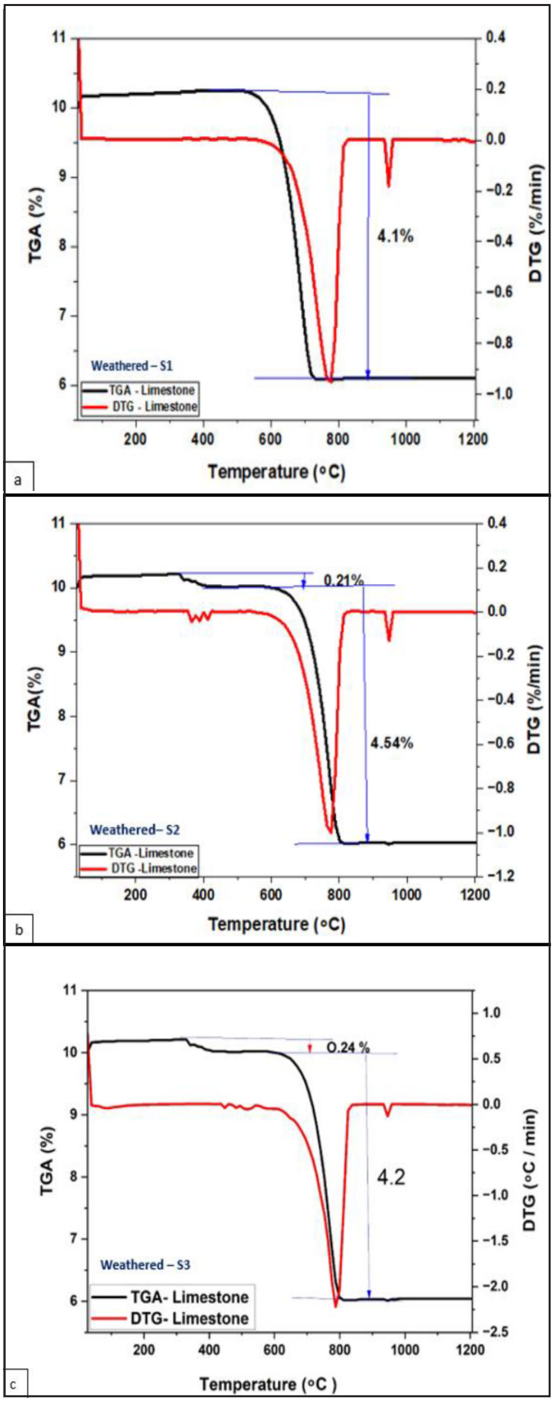

Figure 6: Thermogravimetric analysis of intact limestone samples (a) Weathered – S1, (b) Weathered – S2 and (c) Weathered – S3.

calcium carbonate, and the slope of the baseline changes occurs within the temperature range of 700 – 800°C. In the process of decomposition, both substances liberate carbon dioxide as magnesium and calcium oxides are formed. The pinnacle level for weight reduction was 4.2 %/min happening at 779.62°C.

Surface morphological characteristics - Intact limestone

The morphological characteristics of intact limestone images and data will be presented in this section. Intact limestone samples, as seen by Scanning Electron Microscopy (SEM) image (Figure 7), exhibit a morphology that suggests the characteristics in their original condition. In general, the images have revealed a surface that is smooth and uniform, with few surface imperfections or cracks visible at high magnification. The crystalline structure seems well-defined and unbroken, representing the clean structure of the limestone. Pores inside the intact samples are consistently distributed and very tiny in size, contributing to the overall compaction and low porosity of the limestone. Also, the surface features such as tiny scratches or abrasions, likely sustained through handling and preparation processes, further supporting the integrity of the complete limestone, and the colour remains consistent across all samples, generally showing a light grey.

The microscopy was conducted at 5.00kV with a 10.8mm x 5.00k SE aperture. The presence of larger particles, up to 10.0µm, was notable, indicating potential impurities or variations in composition (Figure 7a). For Intact-S2 sample, it has displayed a relatively narrow particle size distribution, with sizes ranging from 3.33µm to 11.0µm. The particles appeared more spherical in shape. The microscopy was conducted at 5.00kV with a 9.6mm x3.00k SE aperture. There was a distinct peak around 10.0µm, suggesting a prominent size mode in this sample (Figure 7b).

Finally, Intact-S3 sample has exhibited a particle size distribution spanning from 4.82µm to 10.0µm, with an irregular shape. microscopy was performed at 5.00kv with a 10.6mm x 5.00k SE aperture. the distribution showed multiple peaks at 5.31µm, 5.68µm, and 5.19µm, indicative of various size modes. the presence of smaller particles down to 4.76µm was observed as well (Figure 7c).

Table 4: Thermal analysis of samples of weathered limestone.

Sample	Temperature Range (°C)	Weight Loss (%/min)	Peak Temperature (°C)
Weathered–S1	28.90 -142.10	4.1	778.47
Weathered–S2	28.90 -142.10	4.54	778.31
Weathered–S3	28.42 -149.95	4.2	779.62

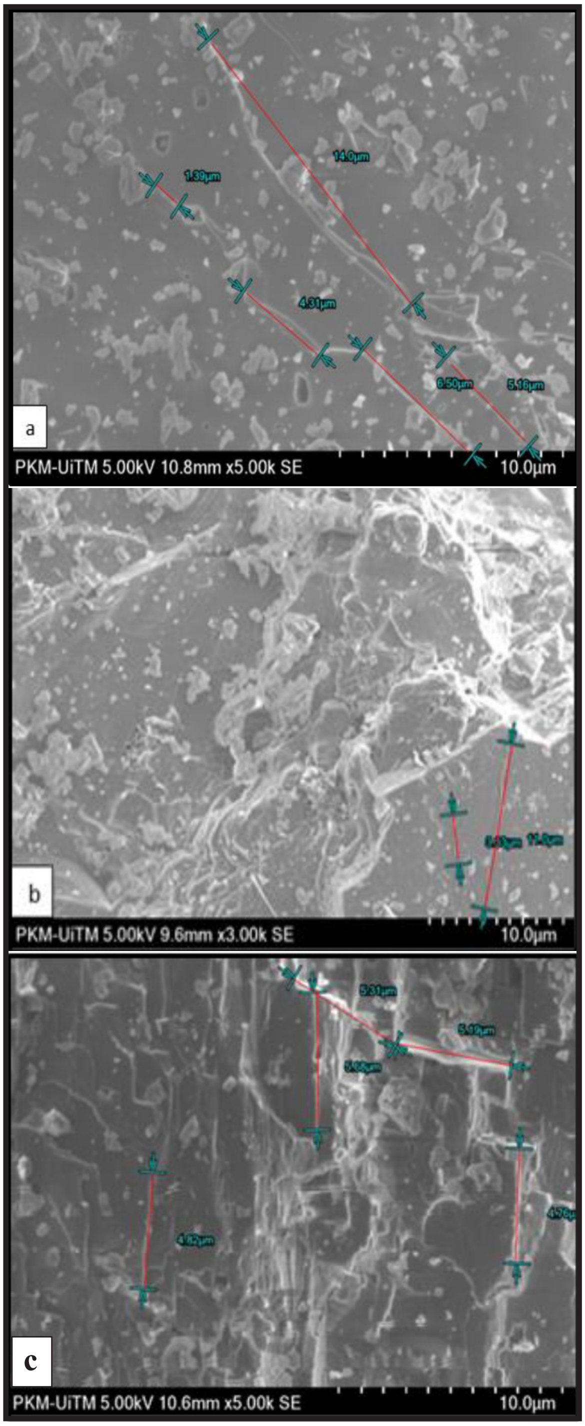

Figure 7: Microscopic examination of intact limestone of (a) Intact – S1, (b) Intact – S2, and (c) Intact – S3.

Table 5 shows the distribution of particle size for intact limestone samples. The assessment of Intact-S1sample has uncovered a different molecule size dissemination, with a reach spreading over from 1.39µm to 14.0µm. The particles appeared to be irregular in shape, with some clustering observed around 4.31µm.

Surface morphological characteristics - Weathered limestone

Conversely, the SEM images examination of weathered limestone samples (Figure 8) reveals a morphology characterized by significant changes brought about by weathering processes in the environment. Under magnification, the surface texture shows distinct traces of weathering and erosion. The texture seems rough and uneven. The broken and fractured crystalline structure shows how the composition of the limestone has changed and deteriorated over time. The weathered samples have larger, more irregular pores, which indicate the dissolution and leaching of mineral components brought on by external influences. Cracks, fissures, and weathering rinds are noticeable surface characteristics that attest to extended exposure to environmental factors. In addition, there are noticeable colour variations that range from lighter to deeper tones, which indicate the level of weathering and the existence of environmental pollutants.

The examination of Weathered-S1 sample has unveiled a wide-ranging particle size of fracture distribution, from 2.98 µm to 21.1 µm. The particles appeared irregular in shape. Microscopy was carried out at 5.00 kv with a 10.7mm x 3.00 k SE aperture. The distribution showed several peaks, particularly at 3.31µm, 3.78µm, 5.93µm, and 9.71µm. This diverse distribution suggests the presence of particles of various sizes and shapes (Figure 8a).

Weathered-S2 sample has displayed a wide-ranging particle size distribution from 1.49µm to 8.24µm. The particles were predominantly irregular in shape. Microscopy was conducted at 5.00kv with a 9.9mm x 3.00k SE aperture. The distribution revealed numerous peaks, specifically round 4.64 µm and 5.46µm, signifying multiple size modes. Moreover, the presence of smaller particles, down to 49µm, becomes evident (Figure 8b). Finally, Weathered-S3 sample showed a very long and deep fractures, demonstrating a particle length distribution

Table 5: Distribution of particle sizes for three samples of intact limestone.

Sample	Particle Size Range (µm)	Peak Particle Size (µm)	Additional Information
Intact–S1	1.39-14.0	4.31	Presence of larger particles, potential impurities or variations
Intact–S2	3.33-11.0	10	Relatively narrow distribution, distinct peak around 10.0µm
Intact–S3	4.82-10.0	5.31; 5.68; 5.19	Multiple size modes, presence of smaller particles

Table 6: Distribution of particle sizes for weathered limestone.

Sample	Particle Size Range (µm)	Peak Particle Size (µm)	Additional Information
Weathered-S1	2.98 - 21.1	3.31; 3.78; 5.93; 9.71	Diverse distribution with various sizes and shapes
Weathered-S2	1.49 - 8.24	4.64; 5.46	Multiple size modes, presence of smaller particles
Weathered-S3	1.89 - 31.0	1.89; 10.6. 9.6	Blended particle size distribution with various modes

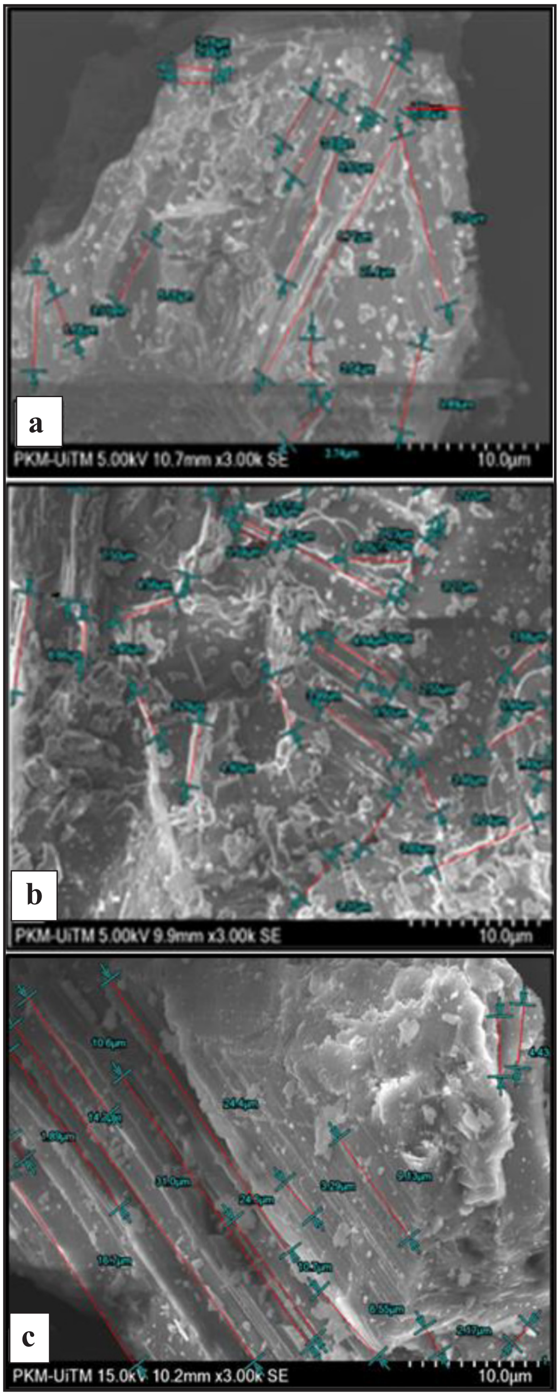

Figure 8: Microscopic examination of weathered limestone samples (a) Weathered-S1, (b) Weathered-S2 and (c) Weathered-S3.

ranging from 1.89 µm to 31.0 µm with an irregular form. Microscopy was carried out at 15.0 kv with a 10.2 mm x 3.00 k SE aperture. The distribution exhibited peaks at 1.89µm, 10.6µm, and 9.6, suggesting a blended particle size distribution with various modes (Figure 8c). Table 6 shows the distribution of particle size for weathered limestone samples.

Weathering-induced fractures and cracks in limestone samples

Based on SEM analyses, the results in the limestone sample exhibit a more uniform particle size distribution, suggesting less agglomeration among particles. This narrower distribution and relatively spherical particle shapes may make the sample more susceptible to fractures or cracks, as the uniformity in particle sizes could increase brittleness. The distinct peak at 10.0µm indicates a prominent size mode, potentially indicating areas of higher stress concentration.

Figure 9 illustrates the presence of fractures and cracks caused by air exposure in limestone samples and their correlation with the degree of weathering.

DISCUSSION

Thermal stability analysis of intact and weathered limestone

Weathered limestone samples usually show a greater weight loss, one of the reasons for increasing porosity. Limestone becomes more porous as a result of weathering

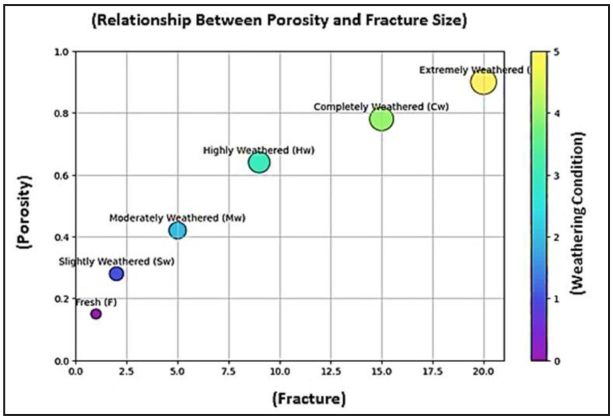

Figure 9: Data showing fractures and cracks caused by air in limestone samples and their relationship with the weathering grade.

processes such as dissolution, abrasion and chemical weathering. Compared to intact samples with lower porosity, these pores allow gases to escape during thermal fracture, resulting in greater weight loss.

Weathering can cause changes in the mineral composition of limestone that led to the leaching of some components or the production of secondary minerals and affect the thermal stability of the rock, which can lead to more weight loss when heated. Also, limestone often has more surface due to fracture and dissolution during weathering processes. More reactive sites are exposed by the larger surface area, which makes the rock more susceptible to thermal failure and causes more weight loss.

The thermal behaviour of limestone can be impacted by weathering-induced structural alterations such as microfractures, mineral recrystallization, and cementation. Elevated reactivity and faster breakdown could result from these modifications, which would increase weight loss. Overall, the higher weight loss seen in weathered limestone samples compared to intact ones during thermal stability analysis can be attributed to a combination of increased porosity, changed mineral composition, higher surface area, and structural changes brought on by weathering processes.

An investigation into the thermal characteristics of limestone via Thermal Gravimetric Analysis (TGA) yields significant knowledge regarding its attributes. The parameters analysed including weight loss, residue formation, peak temperatures, and peak weight loss rates can be accessed via TGA analysis.

Comparison of intact limestone samples indicates consistent thermal characteristics, with stable behaviour demonstrated across all intact limestone samples. Each sample displays uniform degradation dynamics, characterized by identical temperature ranges, inflection points, and peak weight loss rates. For instance, the range of weight loss for intact limestone samples differs minimally, with Intact-S1 sample has losing 3.1% per minute at 728.75°C, meanwhile, Intact-S2 sample has losing 2.4% per minute at 772.90°C, and Intact-S3 sample has losing 3.2% per minute at 734.45°C (Figure 10a). These data reveal a similar pattern of thermal breakdown in intact limestone, with small variances in temperature profiles and weight loss.

In contrast, the impact of weathering on thermal stability becomes clear. Weathered limestone samples demonstrate unique breakdown characteristics compared to their undamaged counterparts. Weathered-S1 sample has indicated an accelerated breakdown rate, with a peak weight loss rate of 4.1% per minute at 778.47°C. Meanwhile, Weathered-S2 sample has displayed heterogeneous degradation behaviour, demonstrated by a peak weight loss rate of 4.54% per minute at 778.31°C. Weathered-S3 sample has displayed a complex thermal degradation pattern, with a peak weight loss rate of 4.2% per minute at 779.62°C (Figure 10b). These data demonstrate that weathering produces structural alterations in limestone, resulting in varied thermal degradation characteristics.

The results align with the findings of Navarre *et al*. (2015), who observed that weathered limestone demonstrates a more intricate and rapid thermal deterioration profile in comparison to intact limestone. The TGA analysis verifies that weathering has a substantial impact on the thermal stability of limestone, rendering it more prone to disintegration at high temperatures.

Surface morphological comparative analysis of intact and weathered limestone

Particle size distributions with mostly irregular forms are revealed by SEM analysis of intact limestone samples (Intact-S1, Intact-S2, and Intact-S3). The particle size distribution curves for these samples show distinct peaks, which are suggestive of uniform particle sizes and shapes. Some samples also show bigger particles, which could indicate contaminants or compositional differences. On the other hand, a SEM image analysis of the weathered limestone samples (Weathered-S1, Weathered-S2, and Weathered-S3) shows cracked surfaces and wider particle size distributions with irregular forms.

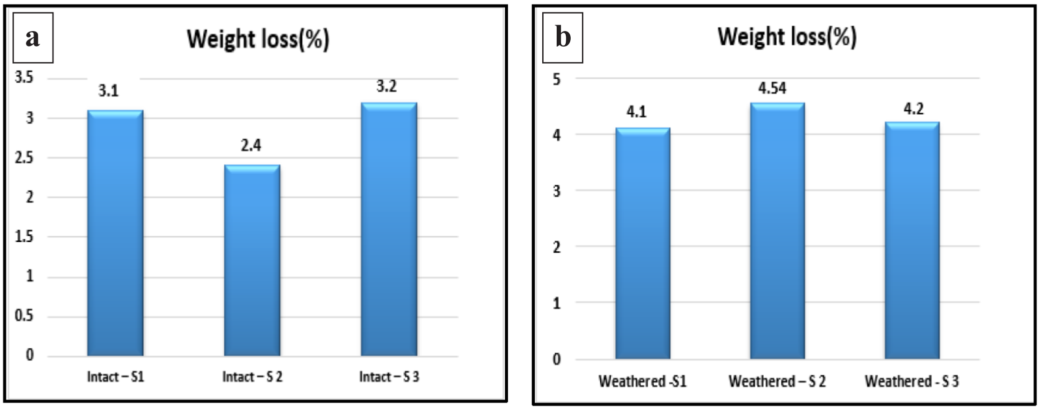

Figure 10: The thermal properties result on weight loss (a) intact limestone samples and (b) weathered limestone.

The presence of uneven shapes and a range of sizes of particles is indicative of the weathering and erosion processes that cause the limestone structure to break apart and disintegrate. In addition, the level of environmental degradation is highlighted by the discovery of smaller particles and extensive fractures in weathered samples. These findings are consistent with the research conducted (Navarre *et al*., 2015), who similarly noted higher porosity and irregular particle sizes in weathered limestone as compared to intact samples. The scanning electron microscopy (SEM) investigation supports earlier research by demonstrating that weathering has a substantial impact on the morphological properties of limestone, resulting in a more diverse and fractured structure.

Significance of the study

The value of this study rests in its extensive evaluation of the morphological and thermal stability variations between weathered and intact limestone. This study will contribute to the understanding of how environmental conditions and long-term exposure effect the integrity and usefulness of limestone in various applications.

a) Enhanced understanding of material properties:

By comparing the findings from SEM image and TGA data, an insight into how weathering processes alter the microstructural characteristics of limestone, such as particle size distribution and surface morphology was gained. The identification of long, deep fractures and increased porosity in weathered limestone, as opposed to the more uniform and compact structure of intact limestone, highlights the significant impact of environmental degradation.

b) Implications for industrial applications:

The thermal stability differences between weathered and undamaged limestone have important ramifications for businesses that use limestone in construction, manufacturing, and environmental cleanup. The higher peak weight loss rates seen in weathered limestone suggest that it is more prone to thermal breakdown, which could impair its performance in high-temperature environments. This knowledge is essential for making sound judgments about material selection and treatment techniques that improve durability and efficiency.

c) Impact on environmental and structural design:

The association between microstructural characteristics and thermal behaviour established by this work emphasizes the need of rigorous material characterization in the design and fabrication of high-temperature-resistant items. This knowledge allows engineers and architects to make more educated decisions regarding the materials they choose, potentially leading to more durable and sustainable buildings.

Finally, this study compares weathered and intact limestone, providing vital insights into how weathering affects thermal stability and morphology. The findings have practical significance for a variety of businesses, including construction, environmental remediation, and historic preservation. Understanding the intricate interaction between microstructural features and thermal behaviour might help us make better decisions and encourage innovation in the use and conservation of limestone. This study not only improves theoretical understanding, but it also provides practical recommendations for applying and preserving this adaptable substance in a variety of disciplines.

CONCLUSION

In this paper, a comparative investigation of the thermal stability and morphology of weathered and intact limestone rocks, acknowledging limestone's multifunctional role in numerous scientific and commercial areas. By applying modern techniques like Scanning Electron Microscopy (SEM) for morphological evaluation and thermogravimetric analysis (TGA) to analyse thermal deterioration behavior, the scientific information concerning limestone's thermal behavior and morphological qualities can be extended.

The study goal is to give useful insights into the complicated link between morphology and thermal stability in limestone. Through extensive TGA research, the effect of temperature on limestone's thermal stability was studied and evaluated the consequent weight reduction. Additionally, SEM morphological examinations offered significant information concerning microstructural characteristics in worn and undamaged limestone samples. Comparing surface morphology, porosity distribution, seams, fractures, and weight changes between weathered and undamaged limestone exposed new understandings about their structural nuances and thermal behaviour.

The major findings revealed considerable differences between weathered and intact limestone samples. Weathered limestone displayed the biggest peak weight loss, but intact limestone demonstrated the highest weight reduction rate. SEM findings further indicated unique particle size distributions across the two versions, with weathered limestone having lengthy, deep fractures compared to unbroken limestone.

These findings have practical consequences for numerous industries and domains, extending beyond theoretical knowledge. Understanding how shape and structure effect heat resistance is vital for decision-making in domains like as building, environmental cleaning, and historical preservation. By discovering patterns and trends that illuminate the delicate relationship between morphology and thermal stability; this study contributes to informed decision-making and promotes innovation across industries also it will give useful information for preservation and implementation in many sectors and domains, supporting informed decisions and promoting innovation.

In conclusion, this work underlines the need of thoroughly knowing limestone's morphology and thermal behaviour to optimize consumption and assure good preservation.

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AUTHORS CONTRIBUTION

The authors affirm their contributions to the paper as follows: study conception and design were led by HK and NNND; data collection: HK; analysis and interpretation of results: HK, NNND, draft manuscript preparation: HK, NNND and SI have contributed with ideas on the design of the experiment. This delineation of individual contributions underscores the collaborative effort and ensures transparency regarding each author's involvement in the research process.

CONFLICT OF INTEREST

The authors, HK and NNND declare no conflicts of interest related to the publication. HK has dual affiliations with the Department of Geology and Mine at Faryab University, Afghanistan, and the Department of Civil Engineering at Universiti Putra Malaysia, Malaysia. NNND is affiliated with the Department of Civil Engineering at Universiti Putra Malaysia, Malaysia and is the corresponding author. There are no financial or personal relationships that could be perceived as conflicts of interest.

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Investigation of potential groundwater sources using electrical resistivity imaging for industrial facilities in Gebeng, Kuantan, Malaysia: A case study

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Abstract: In dry regions with limited access to surface water, groundwater is an essential source of freshwater supplies. This is especially true in areas where there is limited availability of surface water. Industries such as manufacturing make extensive use of water for various purposes, including cleaning, heating, and cooling, the production of steam, use as a solvent, transportation of substances that have been dispersed into it, and as a component of the manufactured product itself. Because of its large size, the groundwater reserve has the potential to become an additional source of water supply for the country, particularly in industrialized regions. The geophysical approach, which geophysicists dominate, has become one of the most prominent methods researchers use to offer the best technique in mineral or resources exploration. Electrical Resistivity Imaging, more commonly referred as ERI, is one of the geophysical techniques that offers a very intriguing method for determining subsurface profiles across a wider region. The primary purpose of this assessment is to assess a potential groundwater aquifer and determine whether it might be economically viable in industrial development facilities. The method described above is suitable for investigating various subsurface conditions. ERI's groundwater investigation using alternative methods, which enhance standard methods, could provide complete and convincing findings, increase efficiency in costing and timing. The ERI survey was carried out with the assistance of an ABEM LS2 Terrameter, which featured 61 electrodes that were planted along a line 400 meters long Line 1, with an electrode spacing of 5 meters (inner) and 10 meters (outer). When the survey was done on Line 2, the electrode spacing was set at 2.5 meters (inner) and 5 meters (outer). The results of the ERI tests indicate that Lines 1 and 2 are good indicators of groundwater presence. Line 2 was undertaken with a length of 200 meter rather than 400 meters, resulting in less data (shallow depth) being obtained. Furthermore, groundwater would have low resistivity (20 to 200 Ωm). An ERI provided a very significantly by enhances groundwater investigations by providing detailed subsurface information that aids in locating and managing water resources effectively. Its ability to integrate with other data sources, coupled with its cost-effectiveness and efficiency that make it an invaluable tool in hydrogeology and environmental management.

Keywords: Groundwater investigation, potential groundwater, electrical resistivity imaging, 2D resistivity, geophysical survey

INTRODUCTION

Many different types of businesses rely heavily on groundwater, making it an important contributor to both economic expansion and development (Cochrane, 2008). Groundwater resources are utilised in a variety of industrial operations in situations where surface water is scarce in quantity and quality of the water is a significant consideration (Petrick *et al*., 2023). According to Ilahi *et al*. (2021), groundwater can be an alternative facility for rural and urban catering for various industrial, agricultural, and domestic uses through several appropriate methods and processes. Manufacturing, mining, oil and gas extraction, energy generating, engineering, and building are all examples of industries that extract groundwater. At the conclusion of many production processes, products require a substantial volume of water in order to be washed and cleaned. As stated by Saimy & Raji (2015), the majority of countries, including Malaysia, rely on surface water supply, and when it comes to water shortage or disruption of water supply, the natural response is

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to hunt for alternatives from other sources, primarily groundwater (Riwayat *et al.,* 2018; Petrick *et al*., 2023). Compared to those of surface water, the expenses of groundwater capital are significantly lower (Saimy & Raji, 2015). Since groundwater is kept below, it can be relied upon even during times of drought, which is especially helpful for countries with a hot temperature. The water is found below the surface of the earth and in the spaces between the soil particles, which is where the greatest amount of water may be stored since it is protected from evaporation caused by the surrounding high temperatures (Hasan *et al*., 2022). It is well-known as a source of water that may be used by all living creatures as an alternative. Industrialists and researchers are faced with the challenge of determining the precise position of the groundwater zone in the subsurface layer (Riwayat *et al*., 2018). The field of geophysics applies the principles of physics to the investigation of the planet Earth by doing measurements on or very close to the surface of the planet (Suryadi *et al*., 2019). Due to its frequent application in geotechnical and environmental studies and research, the geophysical method is frequently regarded as a comprehensive instrument for underground air exploration and investigation (Riwayat *et al*., 2018). Since the beginning of these types of investigations, geophysics has been an important contributor to the advancement of the equipment used, as well as the research and development of methods that produce better results and expand the field's application scope.

Today, groundwater exploration uses a multidisciplinary methodological approach based on the analysis of large-scale geology and tectonic conditions (Sulaiman *et al*., 2022). Addition as stated by Sulaiman *et al*. (2022), for the spatial exploration of groundwater, geophysical and remote sensing methods play a central role. The use of remote sensing and geographic information systems (GIS) has been used in many states in Malaysia, including Selangor, Kedah, Perlis, and Perak, to conduct groundwater surveys (Petrick *et al*., 2023). Comparison in terms of cost and time for soil drilling works, electrical resistivity imaging method in underground water investigation is more economical in terms of cost and time (Suryadi *et al*., 2019; Lin *et al*., 2020). By dividing the landscape into zones with low and high groundwater potential, a groundwater potential map effectively reduces the number of locations where drilling could take place (Hasanuzzaman *et al*., 2022). Nevertheless, the collecting of data in situ is still extremely important for the validation of interpretations that are based on remotely sensed data (Zaini *et al*., 2019; Ishak *et al*., 2021).

According to Riwayat *et al*. (2018), the subsurface water that exists on this planet is a natural resource that cannot be perceived through the lens of time. In the uppermost layer of the Earth's crust, it can be found in a variety of various rock formations, in a variety of different concentrations, and a variety of different depths (Ishak *et al*., 2022). When there was no obvious water flow along the rivers in the distant past, people dug small trenches in the ground to collect groundwater for the purposes of drinking and supplying their other household requirements. In a similar manner, the people who lived in mountainous regions relied on natural springs as their primary source of drinking water. According to Hao *et al*. (2020), in order to investigate groundwater, one must have a comprehensive understanding of the hydrology and geology of the area in question.

Electrical Resistivity Imaging (ERI) is a component of the geophysical technology that is utilised as an initial phase in the process of any investigation of groundwater (Asry *et al*., 2012). ERI has seen significant use on a yearly basis and has been put to use to determine the thickness of the layered media and map the geological environment of existing aquifers (Ishak *et al*., 2021; Zolkepli *et al*., 2023). In addition, ERI has been utilised in order to map the geological environment (Ishak *et al*., 2022; Daud *et al*., 2024). Because of the ease with which the method may be used, its effectiveness, and the fact that it does not involve any damaging processes while obtaining images of the subsurface, it has shown to be a useful tool for assessing groundwater (Ilahi *et al*., 2021; Petrick *et al*., 2023). As stated by Osinowo & Falufosi (2018), ERI is a geophysical active non-destructive test (NDT) approach that produces two-dimensional (2D) or three-dimensional (3D) images of the subsurface's electrical resistivity distribution. The vast majority of groundwater investigations have used the geoelectrical exploration technique of electrical resistivity tomography (ERT) to link the electrical properties of geologic formations with their fluid content (Alshehri, 2023). This has been done in order to better understand how groundwater flows. The key elements influencing electrical resistivity are formation fluid salinity, saturation, aquifer lithology, and porosity (Al-Garni, 2009). Examination of the groundwater's quality has been accomplished with great success using this method in every region of the world. The electrical resistivity method is typically utilised in order to ascertain the boundaries of aquifers in addition to the depth, kind, and thickness of alluvium. In this particular area of research, ERI conducted in order to measure and map the resistivity of the subsurface resources. It also refers to a survey that passes an electrical current down many distinct pathways and measures the accompanying voltage to show the subsurface's electrical properties (Abidin *et al*., 2011). The ERI is predicated on the interaction that takes place between the ground and the flow of electrical electricity (Abdulrazzaq *et al*., 2020). It is sensitive to differences in the electrical resistivity of the subsoil measured in ohm meters.

In its most fundamental form, the resistivity approach evaluates the distribution of the underlying material in terms of its resistivity. Table 1 lists the resistivity values of a selection of the most prevalent common rocks and soil materials published by Loke (2015). Besides that, listed in the same table also presented the resistivity values of a selection of the most pervasive minerals, soils, and water types (Loke, 2015). In general, igneous and metamorphic materials have high resistivity values. The degree of fracturing has the most significant influence on the resistivity of these materials. Fractures are frequently filled with groundwater in Malaysia due to the relatively low water table depth throughout the country. For instance, the greater the fracturing, the lower the resistivity of granite, which ranges from 5,000 ohm/m when wet to 10,000 ohm/m when dried. When these materials are saturated with groundwater, their resistivity values range from a few to a few hundred ohm/m. Soils above the water table are arid and have a resistivity value that ranges from several hundred to several thousand ohm/m.

In contrast, soils below the water table typically have resistivity values of less than 100 ohm/m. In addition to this, the electrical resistivity of clay is noticeably lower than that of sand. In conclusion, the purpose of this investigation is to evaluate the prospective groundwater aquifer that may be harvested in an economically viable manner by conducting a field investigation utilising ERI.

RESEARCH METHODOLOGY

The study had been carried out includes various parts, the first of which is a desk study regarding the study area involved. The second involves field measurements in the problematic areas, and the last is analysing the data obtained. Due to obtaining preliminary information such as geological sites and topography on a global and local scale, as described in the subtopics in the methodology section of this research, the desk study carried out is to consolidate preliminary information data about the study region through existing reports and maps. After that, field measurement was carried out with electrical resistivity imaging (ERI) support. The original data collected during the field work at the location study was ultimately reviewed and processed by utilizing the RES2DINV program. ERI method is utilized in the process of the groundwater resource assessment that is carried out. Two surveys are engaged with Line 1, which has a length of 400 meters and 61 electrodes that are spaced at intervals of 5 meters for the inner spreads and 10 meters for the outer spreads. Concerning Line 2, the electrode spacing utilized was 2.5 meters for the inner spreads and 5 meters for the outer spreads, respectively. Due to the constraints imposed by the available space in the study area, Line 2 has a total length of only 200 meters, making it shorter than Line 1. An ABEM Terrameter LS is used to get the reading.

Table 1: Resistivity of some common materials (Loke, 2015).

Material	Resistivity (ohm/m)	
Granite	5×10^3 - 10^6	
Basalt	10^3 - 10^6	
Slate	6×10^2 - 4×10^7	
Marble	10^2 - 2.5×10^8	
Quartzite	10^2 - 2×10^8	
Hematite Ore	8 – 1×10^4	
Magnetite Ore	0.1 – 1×10^3	
Sandstone	8 - 4×10^3	
Shale	20 - 2×10^3	
Limestone	50 - 4×10^2	
Clay	1 - 100	
Alluvium	10 - 800	
Groundwater (Fresh Water)	10 - 100	
Sea Water	0.2	
Material	**Typical Resistivity, Ωm**	**Usual Limit, Ωm**
Sea Water	2	0.1 – 10
Clay	40	8 – 70
Ground Well and Spring Water	50	10 – 150
Clay and Sand Mixtures	100	4 – 300
Shale, Slates, Sandstones	120	10 – 100
Peat, Loam and Mud	150	5 – 250
Lake and Brook Water	250	100 – 400
Sand	2000	200 – 3000
Moraine Gravel	3000	40 – 10 000
Ridge Gravel	15 000	3000 – 30 000
Ice	10 000	10 000 – 100 000

Study area and geological background

The area being surveyed is located in the Gebeng industrial area (Mukim Sungai Karang) at an approximate latitude of 3°59'33.5"N and longitude of 103°24'27.7"E, which is represented in RSO coordinates as 441486 (Northing) and 601572 (Easting). Figure 1 shows that the study area was formed during the Quaternary period (the last period of the Cenozoic Era). Generally, the Kuantan district sits on a large area of underlying sand within the Titiwangsa range. The surface soils around the Gebeng industrial area are alluvial and mainly comprise peat. Marine and continental deposits of variable thickness are underlying the coastal belt between Kemaman, Terengganu and Kuantan, Pahang. Based on the Mineral and Geoscience Department of Malaysia's available boring and seismic data, the coastal deposit becomes deeper from west to east (towards the coast) and southwards towards Pekan, Pahang.

A study has shown that Gebeng and Sungai Karang areas are underlain by alluvium up to a depth of approximately 38 meters (Akreditasi, 2019). The underlying lithology of Mukim Sungai Karang is an arenaceous sedimentary rock, and it is composed of quartz and feldspar minerals as well as sand-cemented sedimentary rocks (Akreditasi, 2019). Sedimentary rocks form throughout time as a result of erosion and weathering, which is enhanced by water and wind transport. The most common sedimentary rocks in this area are sandstone and siltstone. The sandstone and siltstone have fine grain size, orange to brown in colour, well-rounded, and non-angular grain shape. The grain shape properties depict the great distance transportation of sediment from the source before being deposited and forming bedrock. In addition, the grain is mediumly-sorted, indicating that this area was a shallow marine area. Fossils also indicate a shallow marine environment with high depositional energy (McLaren & Bowles, 1985). Towards the Balok region (west and southwest), igneous rocks such as basalt and granite could be observed abundantly at shallow depths. The coastline's shape is seasonal, and monsoons govern it. During the northeast monsoon (November to February), strong waves are prevalent when the winds blow onshore. On the contrary, the winds are weak and offshore during the southwest monsoon (May to August). Published by Environment Impact Assessment (EIA) Malaysia 2015, the northeast monsoon causes high erosion on the beach while the southwest monsoon causes accretion.

Equipment and methodology of surveying

The instruments that are used to determine the resistivity of materials are detailed in Figure 2, which may be found here. In its most basic form, the apparatus can be separated into three primary parts: the source, the inducer, and the record. A dry cell battery was employed to supply the power for the data-collecting process, while a steel electrode served as the current inducer. The ABEM Terrameter LS2 was utilized in order to record the apparent resistivity data. The apparatus needs to be set up appropriately and follow the method of work to reduce the excessive reading mistake after the analysis. In addition, the area to be studied should be devoid of any surface structures to minimize the disruption along the survey line. At the same time, the electrode plant is being installed.

The resistivity method is an electrical geophysical imaging method that is used to assess the apparent distribution of subsurface resistance. This is accomplished by injecting direct current (DC) into the ground through the use of two (2) current electrodes designated as C1 and C2. Two (2) potential electrodes, designated P1 and P2, are used to determine the magnitude of a potential difference. An electrical imaging system is now mainly carried out with a multi-electrode resistivity meter system. Table 2

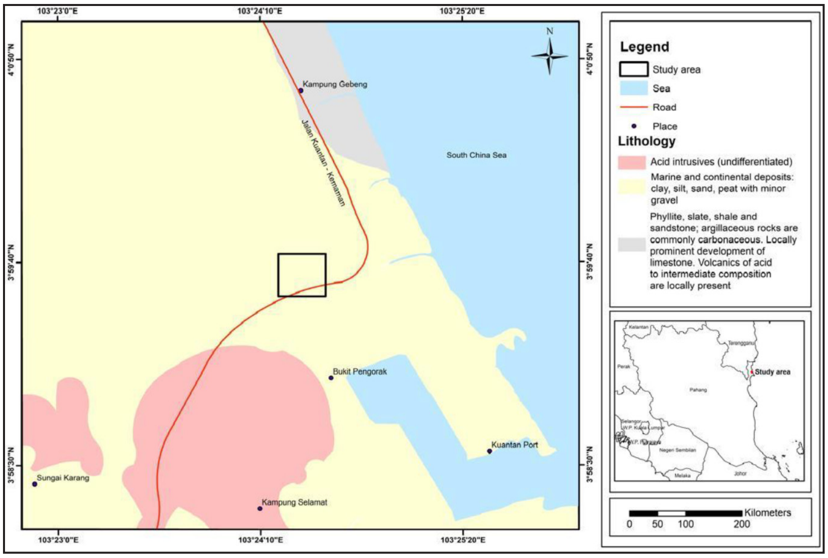

Figure 1: Geological Map of the study area.

Figure 2: Multi-electrode resistivity meter system. Modified from Meterland (2024).

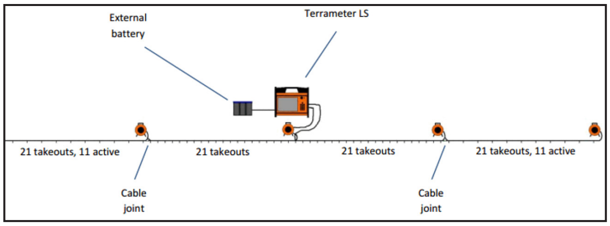

Figure 3: The resistivity cable configuration on field arrangement for Line 1 and Line 2 (Bobachev, 2015).

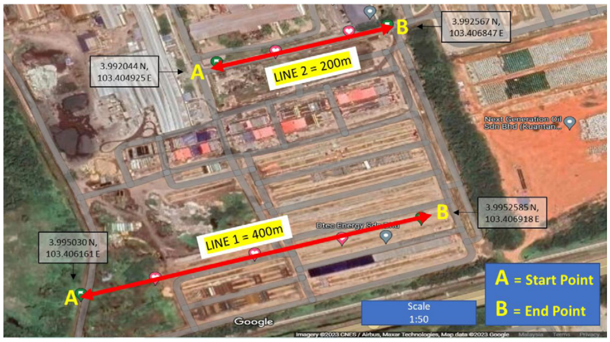

Figure 4: Actual survey line conducted at study area.

and Table 3 show two (2) parts of parameters known as survey lines configuration and receiver parameters that used in this study.

Data acquire and data processing

A total of two (2) resistivity lines have been carried out with different lengths which are 400m for Line 1 and 200m for Line 2 respectively. The resistivity imaging was conducted using the ABEM Terrameter LS2 system. The equipment includes an inducer, source, and record. One of the earliest uses of electrical resistivity is to detect water, distinguish between fresh, brackish, and saline deposits, monitor aquifer decline and recharge, or estimate its extents by scanning a terrain (Suryadi *et al*., 2019; Ilahi *et al*., 2021; Petrick *et al*., 2023). An external battery of 12 volts set up the ABEM Terrameter LS2 source. This surveying works involved 61 steel electrodes combined with 64 transmitters utilized as a current inducer for both survey lines. The resistivity cable configuration on field arrangement is presented in Figure 3 and Figure 4. This equipment creates a record and visualizes the apparent resistivity value, and RES2DINV software was used to finally evaluate, interpret and clarify the raw data acquired from an on-site survey measurement. The data recorded from the exploration work in the field utilizing the Schlumberger protocol method, which is a method that is frequently utilized for work related to exploration (Ishak *et al*., 2022). It produces dense near-surface coverings while producing a measuring pattern that is slightly sparser when the electrode spacing is longer.

Table 2: Total length and electrode spacing of ERI survey line.

Survey Line	Inner Electrode Spacing (m)	Outer Electrode Spacing (m)	Total Length (m)
Line 1	5	10	400
Line 2	2.5	5	200

Table 3: Setting up of the ERI receiver parameters survey line.

Receiver Parameters	Description Setting
Measure Mode	Res
Minimum Number of Stacking	1
Maximum Number of Stacking	2
Error Limit	1.0%
Delay Time	0.4s
Acquired Time	0.6s
Number of IP Windows	8
Record Full Waveform	Yes
Power Line Frequency	60 Hz

RESULTS AND DISCUSSION

Electrical resistivity imaging (ERI)

Figure 5 until Figure 8 below present interpreted two-dimensional (2D) electrical resistivity profiles. The horizontal scale is given in meters for the length of survey lines, and the vertical scale is given in meters for elevation. The results show that the maximum penetration depth for the subsurface imaging is 43m for all surveyed line. The RMS error produced for the 2D resistivity model is lower than 14%. RMS value is used to find the average value of current or instantaneous voltages. It is used when the given variable is positive or negative or the set of given values is random. RMS value can be used to quantify and depict the discrepancy between calculated and observed values. Although the final model should have a low RMS, this does not always mean that it is the most accurate geological model. The resistivity value obtained for this study is ranged from 1 Ωm to 500 Ωm. As seen in the following figures, an overall total of two (2) electrical resistivity lines were planned to travel through the area of interest. According to the Schlumberger methodology, the maximum depths that allow for data coverage in the centre portion of survey lines are between 65 to 90 meters, respectively (Niaz *et al.*, 2021). The resistivity value exhibits a medium range between 0.5 Ωm to 888 Ωm. The low resistivity value of 0.1 Ωm to 10 Ωm presented in the processed ERI profiles are bluish. It is interpreted as alluvium (silty clay), which might consist of salty water (Loke, 2015). The resistivity value range between 10 Ωm to 80 Ωm (greenish and yellowish) is interpreted as alluvium (clayey silt). Resistivity range between 80 Ωm to 500 Ωm, which is presented in orange to reddish in colour interpreted as sand or gravel and may act as groundwater aquifer. The presence of boulders (sandstone clastic rock boulders) and altered rocks are a possibility along this range of resistivity reading. Commonly, the resistivity of 1000 Ωm and above shows the presence of bedrock (igneous, sedimentary, and metamorphic). The topsoil of the survey area consists of various soil types and properties. However, the main soil types observed are clayey silt with mixture of organic matter (humus) and sand at the stream. The variation of soil types such as clayey silt, silty clay and silty sand had contributed to the wide range of resistivity value from 10 Ωm to 888 Ωm. Based on the two (2) resistivity profiles obtained, the overburden soil thickness range between 25 to 40m.

Electrical resistivity for line 1

Figure 5 shows the 2D resistivity model of Line 1 at a depth of 74m from the surface with a RMS of 39.3%. On the other hand, Figure 6 shows the 2D resistivity model of Line 1 at a depth of 43m from the surface with an RMS of 11.2%. The lower the RMS, the more accurate the result. Hence Figure 6 is used for the detailed interpretation of Line 1, while Figure 5 is used for comparison at depth. Based on Figure 6, the topsoil layer could be seen dominated by clayey silt (greenish colour in 2D resistivity model). The profile is dominated by thick alluvial soils with gravel and a minor of sedimentary boulders and altered rocks. Commonly, a resistivity reading of 10 Ωm and below indicates the silt/clay or the presence of saltwater. Freshwater aquifers are commonly found in sand or gravel resistivity range of 10 to 150 Ωm. The resistivity of an aquifer can vary to 500 Ωm. Thus, the orange and reddish area in the 2D resistivity model is marked as sand or gravel (potential aquifer). In contrast, the bluish area is marked as silty clay, stated by Omosuyi *et al.* (2007), that a resistivity range of 20 to 100 Ωm is related to excellent weathering and groundwater potential. In comparison, the 101 to 150 Ωm resistivity is suggestive of medium aquifer condition and potential. Three (3) borehole works are proposed at electrodes 9, 30, and 51 to the depth of 15m, 30m, and 20m from the surface, respectively. Electrode 9 is located at 3.992044 N, 103.404925 E, electrode 30 is located at 3.99236 N, 103.405947 E, while electrode 51 is located at 3.992567 N, 103.406847. The distance of electrodes 9, 30, and 51 from the first electrode location is 80m, 195m, and 300m, respectively.

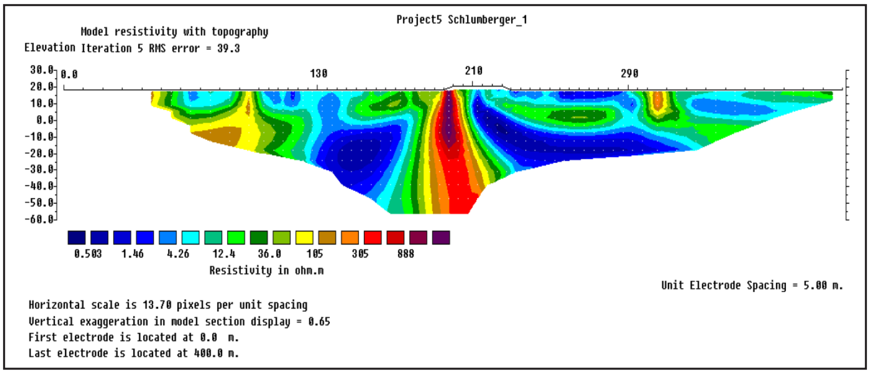

Figure 5: 2D resistivity model of Line 1 (Depth 74m from the surface).

Electrical resistivity for line 2

Figure 7 shows the 2D resistivity model of Line 2 at a depth of 35m from the surface with an RMS of 32.6%, while Figure 8 shows the 2D resistivity model of Line 2 at a depth of 25m from the surface with an RMS of 13.5%. As Figure 7 shows the lowest RMS, it is used to interpret the data for Line 2. The lower resistivity reading, 0.2 to 10 Ωm, indicates the clayey/silty material is present and shown with a bluish to greenish colour in the 2D resistivity model. The orange-reddish area in the 2D resistivity model has a resistivity range of 80 to 200 Ωm, which can be indicated as the sand or gravel, which may act as the water aquifer. Two (2) boreholes are proposed at electrodes 19 and 52 at 20m and 15m depths, respectively. Electrode 19 is at 3.99503 N, 103.406161 E, while electrode 52 is at 3.995285 N, 103.406918 E. For locating water in bedrock, lower resistivity would mean the fractured zone, while higher resistivity indicates the

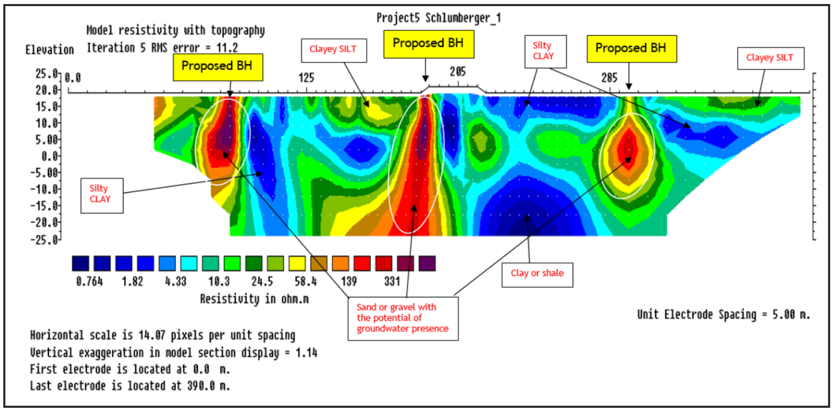

Figure 6: 2D resistivity model of Line 1 (Depth: 43m from the surface).

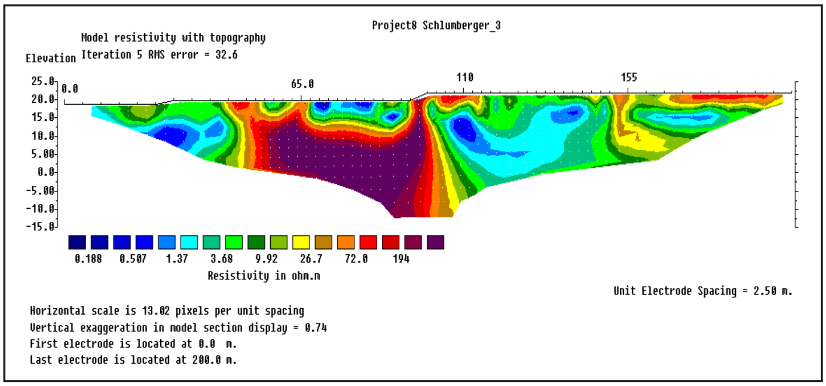

Figure 7: 2D resistivity model of Line 2 (Depth: 35m from the surface).

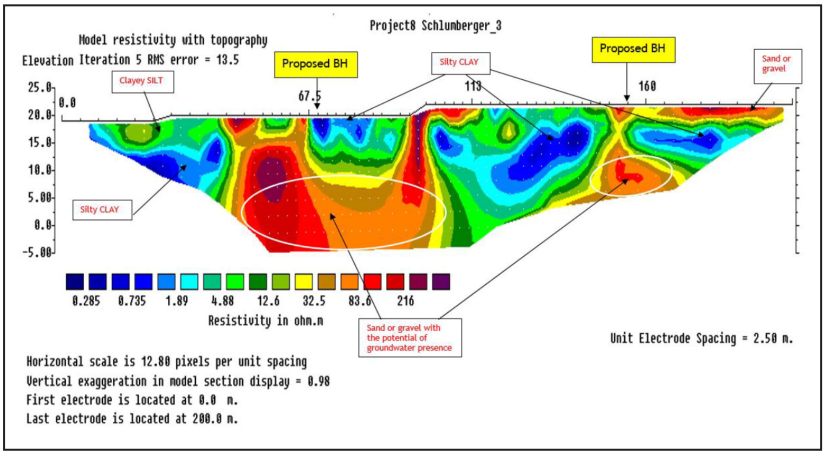

Figure 8: 2D resistivity model of Line 2 (Depth: 25m from the surface).

hard rock. Fractured zone resistivity is lower because the hard rock moisture will collect in the fissures of the fracture zone. Since it contains moisture, it will be more conductive than hard rock, thus having low resistivity. Like in sedimentary areas with thick alluvial, this research study should consider slightly higher resistivity. For example, clay is more conductive (lower resistivity) than sand and gravel. Clay is sticky and wet and not permeable, which means water cannot flow through it; thus it cannot hold water (Agiusa, 2018).

CONCLUSION

Two (2) 2D resistivity imaging profiles of electrical resistivity were acquired in this geophysical survey investigation. According to the findings of the investigation carried out in the Gebeng, Kuantan industrial area, both survey line (Lines 1 and 2) provide good indicators of the presence of groundwater. The length of Line 2 was just 200 meters, in contrast to the length of Line 1, which was 400 meters; as a result, only less data (a shallower depth) was collected. In addition to that, groundwater would have a low resistivity (between 20 and 200 Ωm). The combination of the resistivity reading and the chargeability reading would better interpret the outcome since both readings could be compared and complemented. Because the induced polarization (IP) survey (chargeability) was not carried out as part of this study, the uncertainty rate will be relatively high. Some recommendations for further studies are that more borehole wells should be drilled due to a better understanding of the groundwater in the study area. Since this study is focused on industrial facilities, it can be seen that the ERI method is a non-invasive technique and can reduce the cost of investigation work. In addition, this method can provide high-resolution 2D images of subsurface resistivity, thus enabling detailed mapping of groundwater features such as aquifer boundaries and freshwater interfaces. It also creates a method suitable for various environments where it offers real-time data acquisition and provides flexible depth penetration, making it an invaluable tool for groundwater investigation and natural resource management, and makes ERI an essential tool for ensuring the sustainable management of water resources and monitoring environmental impacts in industrial settings.

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AUTHORS CONTRIBUTION

SD: Conceptualization, writing-original draft preparation, investigation, methodology and data collection; MFI: Supervision, resources and writing review; PII: Data Collection and Validation; MFZ: Data collection, validation and writing review.

CONFLICT OF INTEREST

The authors affirm that they do not have any known competing financial interests or personal ties that could have looked like they had an influence on the work that is disclosed in this study.

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Effectiveness of sieving and grinding in measuring the concentration of rare earth elements from ion adsorption clay in Lumut, Perak

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Abstract: This study examines the effect of pre-treatment techniques of sieving and grinding on the concentration and extractable yield of rare earth elements (REEs) from ion adsorption clay (IAC) in Lumut, Perak. Three 3 kg samples were prepared: raw (untreated), sieved to <600 µm, and ground to <600 µm. The REE concentrations in the digested samples were analysed using Inductively Coupled Plasma Mass Spectrometry (ICP-MS), while the mineralogical composition was determined using X-ray Diffraction (XRD). The results showed that sieving significantly enriched light REEs (LREEs), with La and Nd up 38.7% and 40.1%, respectively, compared to the raw sample. However, only 1.65 kg of sample was retained post-sieving, resulting in a lower total recovery of La (76.3%). In contrast, grinding retained 2.92 kg and yielded a higher La recovery (84.5%) despite a lower concentration. These findings demonstrate a trade-off between concentration and mass yield: sieving is effective for enriching REEs in fine fractions, whereas grinding maximizes total extractable REEs. This study emphasizes the importance of integrating both concentration and mass balance in evaluating REE processing methods. It supports sieving as a selective enrichment technique and grinding as a superior alternative for maximizing total recovery from IAC.

Keywords: Ion adsorption clay, rare earth elements, sieving, grinding, minerals, Malaysia

INTRODUCTION

Rare earth elements (REEs) play a vital role in modern world technology today due to their distinctive properties, making them essential for various applications. There are 17 types of REEs, each having their own unique properties such as luminescence, magnetism, and catalytic capabilities (Haxel *et al*., 2002). REEs are utilised in various industries, including advanced manufacturing and electronics, serving as catalysts, additives, and essential components in specialized materials (Gschneidner *et al*., 2009). REEs are also essential components in magnets used in microphones, electric scooters, and motherboards. Additional examples of broader REEs application include smartphones, monitors, televisions and smartwatches. The relevance of REEs continues to grow as technology advances, making them impossible to be replaced, becoming an essential component of our contemporary world.

REEs are typically classified into two groups based on their atomic weights: light rare earth elements (LREE) and heavy rare earth elements (HREE) (N.S. Duzgoren-Aydin & Aydin, 2008). LREEs namely lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), and samarium (Sm) are more abundant and have a broader range of applications in electronics and metallurgic industries. Meanwhile, HREEs consist of europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), and lutetium (Lu). It is normally less abundant but has more specific applications, such as magnet production for batteries. Understanding both HREE and LREE categories is essential for distinguishing the distinctive properties and applications of REEs. This can help to develop a successful and environmentally friendly technology.

Malaysia is poised to become a leading producer of REEs, with ion adsorption clay (IAC) deposits accounting for a substantial share of its resources. The IAC is primarily composed of clay minerals with the unique capacity to preferentially adsorb rare earth ions from

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water (Sanematsu *et al*., 2011). According to Sobri *et al*. (2023), IAC makes an extremely valuable REEs source, specifically LREEs. Weathered granite is closely related to IAC, and clay minerals found in IAC have a strong affinity for rare earth ions. Thus, IAC deposits are ideal for rare earth element extraction (Khairulanuar *et al*., 2022).

However, the development of effective physical mineral processing techniques prior to REE extraction remains a challenge. The extraction of LREE from IAC is also hampered by complex extraction techniques (Gkika *et al*., 2024) and high processing costs (Saskatchewan Research Council, 2015) are also challenges faced in. As a result, there is an urgent need for research into developing efficient and environmentally friendly techniques to process the IAC before extracting REEs from IAC deposits. Mineral processing is a critical step in many industrial processes, particularly those involving solid materials. It begins from treating the material in preparation for further operations like heat treatment and mechanical processes (Bamber *et al*., 2008). The most common pre-treatment techniques are sieving and grinding.

The particle size reduction process for solid material is known as the grinding method. The intended particle sizes and the specific properties of the material used dictate the grinding method used. Grinding processes can be classified into three types: which are crushing, ball milling and mortar grinding. Crushing is used to break down large chunks of material into smaller pieces. In contrast milling is utilized for finer particle sizes and is frequently associated with the use of balls or other grinding media. Grinding, on the other hand, is influenced by characteristics such as particle hardness, which requires a high energy level when working with harder materials. Particle size distribution has an impact on the grinding process as the initial size distribution of the material influences the grinding time and energy required (H. Du Plessis *et al*., 2007). Finally, the type and size of grinding media affects grinding efficiency and particle size distribution.

Sieving is the process of separating particles according to their size. It involves passing the material through a sieve or mesh with specific openings. Particles smaller than the openings pass through, while larger particles remain on the sieve. There are three types of sieving: mesh sieves, perforated plate sieves, and vibrating sieves. A mesh sieve employs wire mesh or woven fabric to sieve, whereas a perforated plate sieve uses holes in the plate. Vibrating sieves use wire mesh sieves that vibrate to improve separation efficiency, such as the ROTAP Sieve equipment used in most laboratories. The particle size distribution in the material impacts the efficiency of sieving, as does the size of the mesh, which plays a major role in sieving, as the larger the openings of the sieve, the faster the material can be sieved. Mesh size also determines the separation cut point in the material being sieved. Sieving techniques might also affect the sieving process. The method used to agitate the material on the sieve can influence the separation efficiency. Grinding and sieving are critical pre-treatment processes adopted by various industries, including mining, metallurgy, pharmaceuticals, and food processing. By reducing the particle size and separating materials based on size, grinding and sieving can improve the efficiency and product quality of subsequent processes (Justiniano *et al*., 2022).

Geological setting

The study area, which coincides with the IAC location, is in Lumut, in Manjung District, Perak (Figure 1). Manjung District is in the western region of Peninsular Malaysia. Even though Manjung is not directly positioned within the Bintang granite range, it is still geologically impacted by the granite intrusion. Granites in Peninsular Malaysia are classified into I-type in the Eastern Belt, S-Type in Central Belt and both I-type and S-Type in the Western Belt. According to Frost & Ronald Frost (2011), the granite in the study area is an S-type granite.

The formation of the IAC deposit in the study area is closely linked to the region's geological history. Over millions of years, weathering processes on the granite and granodiorite have released REEs into the environment (Middelburg *et al*., 1988). In the Manjung region, clay minerals in the granite adsorbed rare earth ions, resulting in the formation of IAC. The presence of major clay minerals such as kaolinite, illite, and montmorillonite, as observed in the Bintang range granite, is key to the geological characteristics of the IAC deposits in Lumut (Yaraghi *et al*., 2020). Lumut's IACs are recognized for having relatively high concentrations of REEs, particularly La, Pr, and Nd. The distinct geological conditions in Lumut have resulted in favourable environments for the formation of the IAC deposits. Consequently, this area has become an important source of REEs for Malaysia.

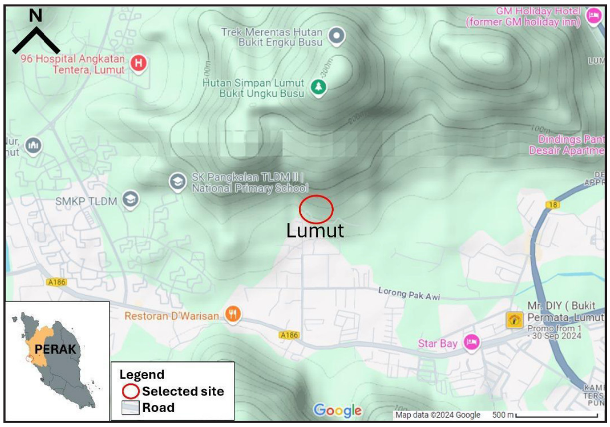

Figure 1: Map showing the location of the study area.

REEs deposits are generally classified based on their formation mechanism and mineralogical properties. Bünzli & Mcgill (2018) noted that the primary REEs deposits are the result of igneous and hydrothermal activity, whereas secondary deposits, mainly placer deposits and ion-adsorption clay deposits, are formed by weathering and sedimentary processes. Chemical weathering processes caused the REEs concentration within igneous weathering profiles, forming placer deposits (Fu *et al*., 2019). However, ion-adsorption clay deposits contain a higher concentration of REEs. Weathered granite crusts form in temperate and tropical climates as a result of numerous processes, such as metamictization and the presence of slightly acidic surface conditions that cause bedrock minerals to transform into secondary minerals such as clay minerals (White & Brantley, 2003). The metamictization process causes radioactive minerals to change texture from completely crystalline to fully metamictized forms (Meldrum *et al*., 1998).

Minerals containing REEs include high concentrations of radioactive elements, particularly uranium and thorium, which can cause host minerals such as micas and feldspars to partially erode in texture, increasing the likelihood that some rock-forming minerals will convert to clay minerals (Balan *et al*., 2001). Samples were collected along the "Lorong Mohd Nazir" road, on an exposed outcrop by the hillside. Surface sampling was conducted, of which about 1 meter of exposed outcrop depth was removed to collect approximately 10 kg of fresh soil sample.

METHODOLOGY

Sample collection and processing

The methodology adopted for this research mainly focused on the pre-treatment of the IAC. Approximately 9 kg of samples were collected from the study location in Lumut. The sample collected from the outcrop (Figure 2) was a whitish-beige coloured clay. Due to the moisture content, the grain size is generally fine, with small clumps of clay, while orange-coloured lines indicate the presence of iron oxide. Grinding and sieving are two common pre-treatment methods for preparing materials for further processing. The two techniques are crucial for reducing particle size, improving homogeneity, and removing impurities before they undergo the REEs extraction process (Khanuja & Dureja, 2021).

All the samples were air dried to avoid any additional changes in chemical properties that might result from heat drying. The samples were then coned and quartered to obtain a representative sample, which was subsequently divided into three equal portions weighing 3 kg each, as outlined in Figure 3. To ensure equal weight, the samples were weighed using a measuring balance. The first batch sample labelled Sample A was preserved as a raw sample to determine the REEs concentration and mineral composition without any pre-treatments. The results from Sample A were used as a theoretical reference value for comparing the other two samples. The second batch was sieved to -600 microns using a ROTAP Siever and designated Sample B, while the third batch was grinded to -600 micron with a mortar grinder and labelled as sample C. The ROTAP Siever and mortar grinder were obtained from the Geoscience Laboratory of University Technology Petronas (UTP). After pre-treatment, samples A, B, and C were sent for X-ray diffraction XRD and Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) analysis to examine the mineral composition and determine the concentration of REEs in the samples, respectively. The XRD analysis was conducted by Orogenic Resources Sdn. Bhd. in Hulu Langat, Selangor, where they used the

Figure 2: On-site view of sampling point.

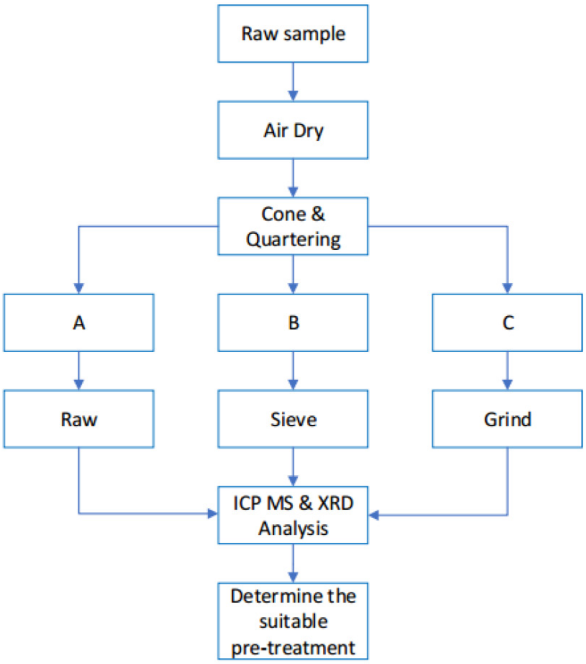

Figure 3: Methodology flowchart of the study.

PDXL software to interpret the XRD graph. Meanwhile, the ICP-MS analysis was conducted at the Rare Earth Element Analytical Laboratory at UTP.

Using the ICP-MS analysis results, the percentage of enrichment from Sample A was determined. The percentage of recovery was calculated using the formula below to determine the optimal pre-treatment method for REEs concentrated in the IAC:

Relative Enrichment % = (*Actual concentration*)/(*Theoretical concentration*) * 100% (1)

Whereby,
Actual concentration = The concentration of REEs from Grind or Sieve sample
Theoretical concentration = The concentration of REEs from Raw sample

Following the pre-treatment process, some samples from Sample B and Sample C were either lost or retained. Sample B retained 1.65 kg from the original 3 kg of the total sample processed, whereas Sample C retained 2.92 kg with the remaining 0.08 kg lost during the grinding process. The total mass of each element was then calculated followed by the actual percentage of recovery. The formulas are as below:

Element mass (*mg*) = *concentration* (*ppm*) * *retained sample mass* (*kg*)

Recovery % = (*Element mass in processed sample* (*Sample B or C*))/(*Element mass in Sample A*) * 100%

Geochemical analysis

• XRD analysis

The sample preparation for XRD analysis began by grinding the obtained sample in a pulveriser to an estimated 50-micron particle size. The sample was mounted onto a suitable sample holder, which is often in round shape. The surface was then flattened and smoothed for a uniform x-ray exposure. The sample was also pelletized, when necessary, before the start of the analysis. Though optional, pelletizing is typically used if the sample is unable to hold its shape and is scattering around.

XRD graphs looks way more complicated. XRD graphs comprise the X-axis representing the diffraction angle of X-rays, and the Y-axis representing the intensity (counts). Each peak corresponds to a set of planes within the crystal structure that satisfy Bragg's Law, indicating a specific crystal structure and lattice spacing. Bragg's Law relates the 2θ value at which a peak occurs to the spacing of the crystal planes, also known as d-spacing. The peak intensity reflects the number of crystal planes diffracting X-rays at that angle, indicating the degree of crystallinity and preferred orientation.

To interpret the graphs, the peaks were identified on the graph. The peaks were then assigned to crystal planes, by matching the peak positions which is the 2θ values with the corresponding crystal planes using reference ICSD databases. The peak intensities were quantified by measuring the height or area of each peak to determine the relative intensity of each reflection, followed by the PDXL software to quantify the minerals. Once the mineral was identified, all identified minerals were selected from the database and compared to the measured diffractogram to quantify the values using Rietveld refinement in the PDXL software. Lastly, the XRD analysis results were displayed in a table format. The untraced peaks were considered as total clay (undetectable in this process).

• ICP-MS analysis

There are several digestion methods, which are divided into two categories: open vessel digestion and closed vessel digestion. Open vessel digestion often employs a steam bath or hot stirrer., whereas manual digestion employs both a steam bath and hot plate stirrer, as well as hydrofluoric acid, sulphuric acid and hydrochloric acid. In the fusion diffusion method, x-ray flux, hydrogen peroxide with nitric acid or hydrochloric acid are used alongside a hot plate stirrer. Meanwhile for closed vessel digestion, a microwave system is used. There are two methods: pressurized autoclaves using nitrogen gas and nitric acid or using aqua regia, which does not require gas. This is dependent on the type of microwave machine used. Cross contamination and undissolved silica are two common challenges encountered throughout each stage. Silica only digest when using hydrofluoric acid but if there is no hydrofluoric acid present, filtration of the digested solution is carried out once it has competed the digestion.

In this study, Anton Paar's Microware Digestion System was employed for closed vessel digestion without external pressure using nitrogen gas in. About 200 mg of samples was weighed using a weighing scale and placed in the digestion vessel. The vessels were then placed in the fume hood and filled with 9 ml of nitric acid and 3 ml of hydrochloric acid. The vessels were sealed tightly and placed into the machine to digest using the EPA 3051A procedure. After digestion, the digested samples were filtered and transferred to a 100 ml volumetric flask, where ultrapure water was added up to the 100 ml line mark on the flask before being sent for ICP-MS analysis.

ICP-MS analysis is used to determine the concentration by elements. To reduce the contamination effect on the machine, dilution is required prior to starting the analysis. Digested solids samples were already diluted in the filtering and transfer process to the volumetric flask from the vessel. Meanwhile, liquid samples such as leachate, were diluted to x100 dilution in a 25 ml volumetric flask

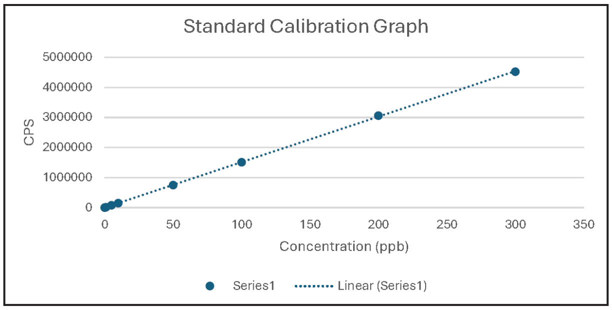

Figure 4: Standard calibration graph.

prior to analysis, and 2.5 ml of the liquid samples were pipetted into the flask, which was then filled with ultrapure water up to the indicated line. The flask was shaken to thoroughly mix the solution, transferred to a sample vial and lastly placed in the machine for the analysis.

The findings of the ICP-MS analysis are directly provided in table format. To cross-verify the results, the standard calibration graph was manually plotted for each element. Figure 4 depicts an example standard calibration graph of one of the elements analysed, plotted count per second (cps) against concentration (ppb). The cps of each element from each sample was compared in the graph and the cross-verification was carried out.

RESULTS AND DISCUSSION

XRD analysis

Table 1 shows the mineral composition of a sample analysed in three distinct states: Sample A, Sample B and Sample C, expressed as a weight percentage (%W). Table 1 summarises XRD results from APPENDIX A (i, ii, & iii) to enhance clarity and comprehension. The XRD data suggest that there are six types of minerals: quartz, plagioclase, K-feldspar, calcite, gibbsite, and total clay. Quartz, plagioclase, and K-feldspar are the most prevalent minerals in all three samples, indicating that the source rock material is composed of these minerals. Physical mineral processing has significantly altered the mineral composition, particularly in terms of quartz, plagioclase, and total clay weight percentages. Following the sieving process, the percentage of quartz decreased significantly, but the percentages of plagioclase, K-feldspar, and total clay increased, indicating that the sieving removed a portion of the quartz-rich material. There is also a slight decrease in the weight percentage of quartz and plagioclase in Sample C compared to Sample A. The weight percentages of minor minerals such as calcite and gibbsite vary slightly across different samples. To ensure accuracy, the total mineral composition of each sample was normalized to 100%, accounting for all detected phases. Overall, the grinding and sieving pre-treatment methods influenced the mineral composition; whereas the weight percentage of predominant minerals remained consistent with variations observed among the minor components. This XRD analysis is crucial for understanding the geological characteristics of the samples and assessing their potential applications.

ICP MS analysis

The ICP MS analysis results for Samples A, B, and C from Appendix B are plotted in Figure 5. The x-axis lists the REEs, while the y-axis displays the concentrations of the elements in parts per million (ppm). Each element and its concentration are represented by individual bars on the graph. The samples mostly contain higher concentrations of various REEs, including La, Ce, Pr, Nd, and Y. The sieving and grinding processes influenced the overall REEs concentration, whereas a smaller particle size impacted the concentration of La and Ce, for example, resulting in an increase in their concentration following the process.

On the other hand, some REEs, such as Nd and Sm, have constant or decreased concentrations. Materials rich in rare earth elements are more likely to contain abundant LREEs than HREEs, which can be associated with the REEs distribution. La and Ce concentrations increased significantly, suggesting that they were potentially extracted during the leaching process. Several factors

Table 1: Summarized XRD results in weight percentage.

Bulk Mineralogy Composition (wt%)			
Mineral \ Sample	Sample A	Sample B	Sample C
Quartz	37.2	22.3	36.1
Plagioclase	14.6	21.7	11.3
K-Feldspar	28.7	27.5	28.2
Calcite (Fe-Cal)	0.2	0.4	0.5
Gibbsite	3.8	4.2	3.1
Clay	15.5	23.9	20.8
Total	100.0	100.0	100.0

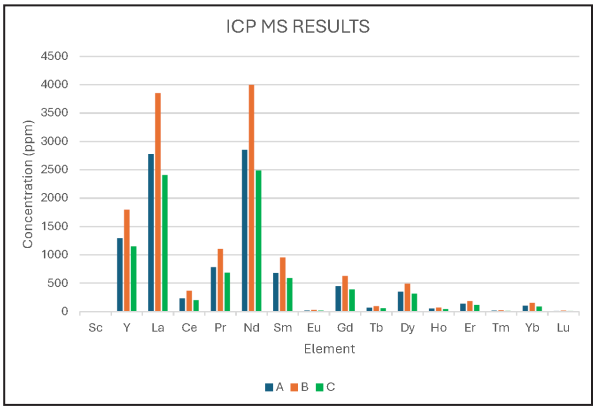

Figure 5: ICP-MS results for Samples A, B, and C.

such as particle size distribution, mineral liberation and removal of impurities, may have contributed to the higher concentration of REEs in Sample B compared to Samples A and C.

There are different particle size particle and sieving method to sorts the sample into the specific categories. The increased concentration for the sieved sample could be attributed to the REEs' association with a specific particle size. Furthermore, sieving can aid in the release of REEs from the associated REE-bearing minerals, greatly improving REEs extraction. This approach will be advantageous for releasing bonds between the REEs and REE-bearing minerals. Furthermore, by directing to a higher concentration of the elements in sample B, sieving can effectively remove impurities that may delay the analysis or the extraction of REEs.

Sample C has a lower REEs concentration than Samples A and B, most likely due to particle size reduction, alterations in mineral composition, and the loss of small particles in dust form. Grinding appears to have reduced the particle size and increased the surface area of exposure of the REE-bearing mineral, but has also produced a finer matrix, making REEs extraction more challenging. Furthermore, mechanical stress is exerted during the grinding process, altering the composition or structure of the minerals and affecting approachability of the REEs inside the mineral lattice. Another factor contributing to the decreased concentration of REEs in Sample C is the loss of sample, which may contain REEs, during the grinding process in the form of dust or fine particles.

Relative enrichment and true recovery

Relative enrichment

Relative enrichment can quantify the difference in REEs concentration (in ppm) after sieving and grinding, using the raw sample (Sample A) as a baseline. Figure 6 depicts the relative enrichment (%) of each element in the sieved sample (Sample B) and ground sample (Sample C), compared to the raw sample. Across all REEs, sieving (Sample B) produced higher relative enrichment compared to grinding (Sample C). Light REEs (LREEs) such as La, Ce, Pr, and Nd were significantly enriched in the sieved fraction, with La increasing by 38.7% and Nd increasing by 40.1% compared to the raw sample. This suggests that the <600 µm fine fraction remained after sieving the preferentially concentrated REE-bearing minerals, which can be attributed to the physical separation of REE-hosting clays from coarser quartz and feldspar. Conversely, the ground sample (Sample C) exhibited lower relative enrichment values, with La and Nd decreasing by 13.3% and 12.8%, respectively, relative to the raw sample. This suggests that grinding, while reducing particle size, may have homogenized the sample material without significantly enhancing REE concentration. Additionally, grinding may generate very fine dust particles that are either lost or difficult to fully digest, slightly diluting the apparent REE content. For heavy REEs (HREEs), both processing methods produced a more moderate effect, with enrichment levels varying between elements. In several cases, sieving slightly increased HREE concentration, but the overall trend indicates that LREEs benefitted the most from the sieving process.

Total recovery

Figure 7 compares the total recovery of REEs from the initial 3 kg of raw material for the sieved and ground samples, with retained weights of 1.65 kg and 2.92 kg, respectively. This combines both the REE concentration (ppm) and the actual mass retained after processing, providing a realistic estimate of extractable element mass for each approach. While sieving increased ppm concentrations in many REEs, this did not translate to higher total recoveries. For instance, although La concentration increased from 2779 ppm in the raw sample to 3853 ppm in the sieved sample, only 1.65 kg of material was preserved after sieving. The recovered La mass was 6.36 g, which accounts for just 76.3% of the original La amount present in the raw sample. In comparison, the ground sample (Sample C) retained nearly the full mass (2.92 kg), and despite having a lower La concentration (2411 ppm), it yielded 7.04 g of La, or 84.5% recovery, which is closer to the original raw sample yield of 8.34

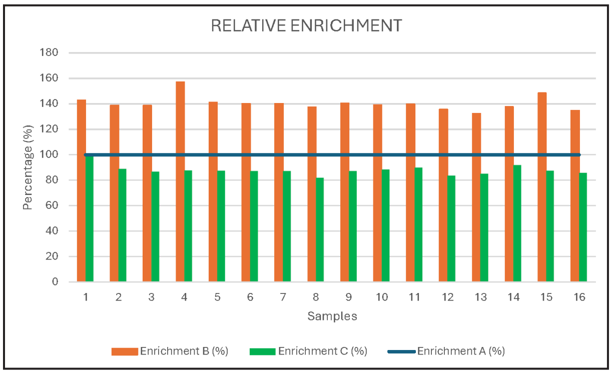

Figure 6: Relative enrichment percentage graph.

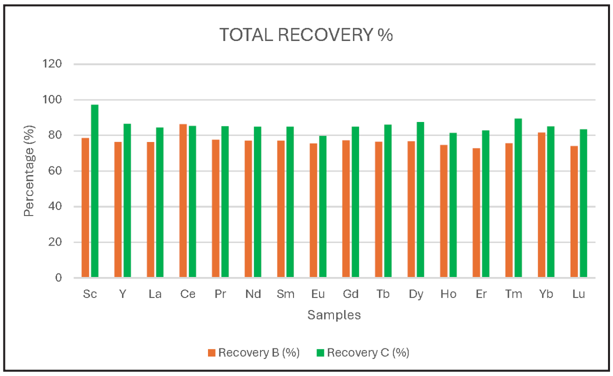

Figure 7: Total recovery percentage graph.

grammes. The element mass can be referred in APPENDIX D. This trend is consistent across most REEs: grinding recovers more total REE mass, while sieving enriches REEs in the retained fine fraction but discards coarse material that still contains recoverable REEs. These findings underscore the importance of mass balance when evaluating processing techniques. High concentration does not imply high recovery, and any preprocessing methods that discards part of the sample (e.g., sieving) must be evaluated for its overall impact on extractable yield.

Interpretation

The comparative analysis of REEs concentration and mass recovery across the raw (Sample A), sieved (Sample B), and ground (Sample C) samples reveals vital insights into the effectiveness of pre-treatment methods for processing IAC. A better understanding of processing efficiency is obtained by examining both relative enrichment (concentration difference) and total REE recovery (mass yield from original sample). The sieved sample (Sample B) exhibited a significant increase in REE concentration (ppm) relative to the raw sample, particularly for LREEs such as La, Ce, Pr, and Nd. For example, the La concentration increased from 2779 ppm in the raw sample to 3853 ppm in the sieved sample, representing an enrichment of approximately 138.7%. This suggests that sieving effectively concentrated REE-bearing clay particles in the <600 µm fraction while removing non-REE-bearing coarse material (e.g., quartz, feldspar). In contrast, ground samples (Sample C) revealed either minor enrichment or slight dilution of REE concentrations when compared to the raw sample, implying that homogenization alone is less effective in concentrating REEs within the sample matrix. Despite higher concentrations, the sieved sample retained only 1.65 kg of the original 3 kg mass, resulting in a reduced total REE recovery. Only 6.36 g of La was recovered, compared to 8.34 g in the raw sample, for a recovery rate of 76.3%. In comparison, the ground sample retained 2.92 kg of material and recovered 7.04 g of La (84.5% recovery), demonstrating that grinding, while less efficient at concentrating REEs, preserved more of the sample and therefore had a higher overall extraction potential.

CONCLUSION

This study provides a detailed evaluation of the mineral composition, REE potential, and pre-treatment effectiveness in processing ion adsorption clay (IAC) from Lumut. The analysis revealed a strong correlation between mineral assemblage and REE concentration, with plagioclase and gibbsite identified as key REE-hosting minerals (Li & Zhou, 2020). The ICP-MS results demonstrated that sieving increased the concentration of light REEs, with La and Nd enriched by 38.7% and 40.1%, respectively. However, this occurred at the expense of mass loss, as only 1.65 kg of material was retained, resulting in a lower total recovery of La (76.3%) compared to the raw sample. In contrast, grinding retained 2.92 kg of sample while achieving a higher total recovery of La (84.5%), despite its lower concentration. These findings highlight a trade-off between enrichment and recovery: sieving improves REE concentration for selective extraction, while grinding maximizes overall yield. The choice of method should align with the intended processing objective. Overall, this research underscores the significance of addressing both concentration and mass balance when evaluating pre-treatment strategies. Optimized processing, tailored to the mineralogical context of the deposit, can significantly enhance REE extraction efficiency from IAC.

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AUTHORS CONTRIBUTION

T.K. - paper conceptualization, literature review, sample processing, data compilation, analysis and interpretation, figure drafting, writing and editing; M.S.B.I. - interpretation, review, writing and editing.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in connection with this article.

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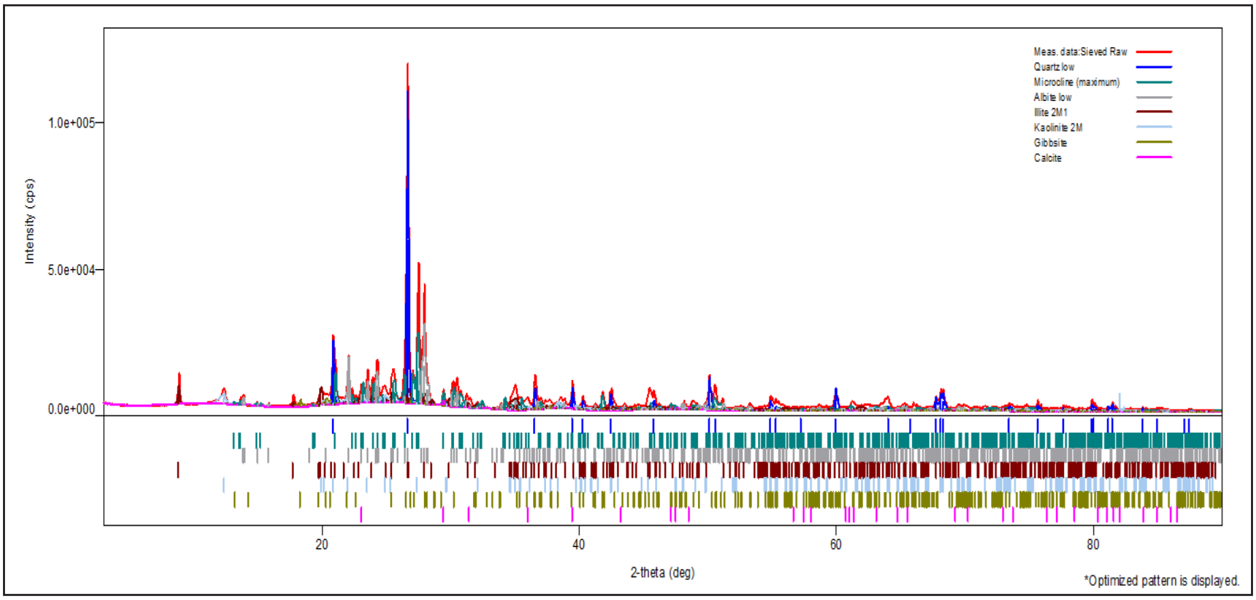
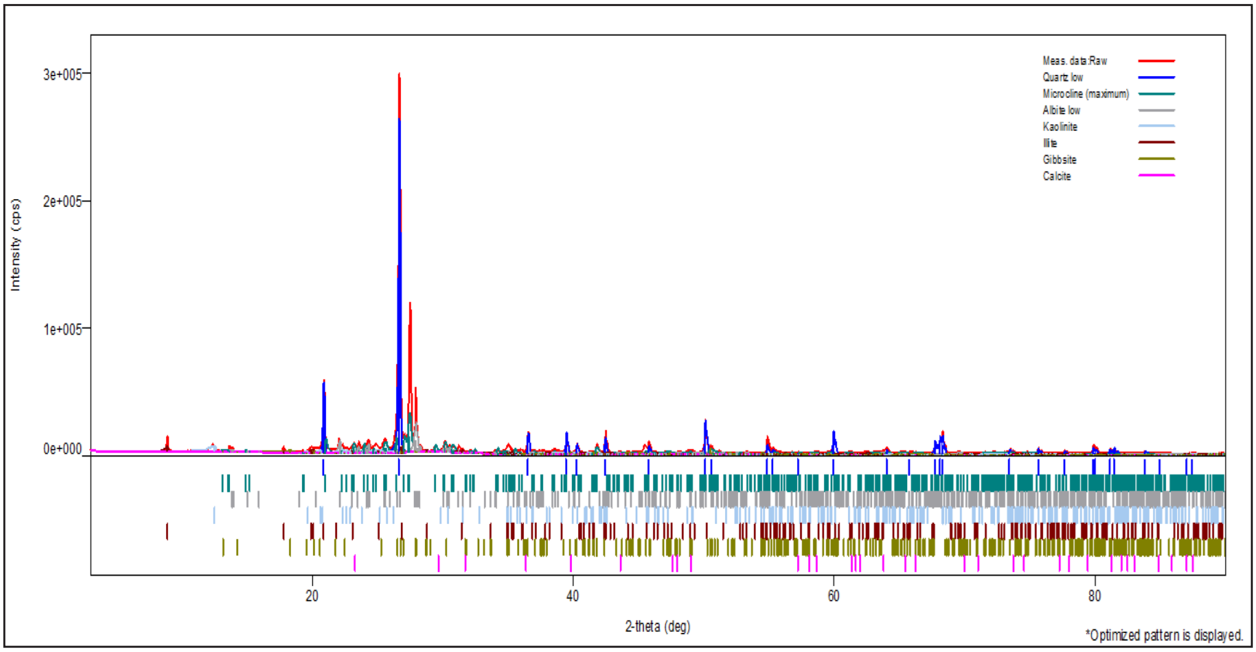
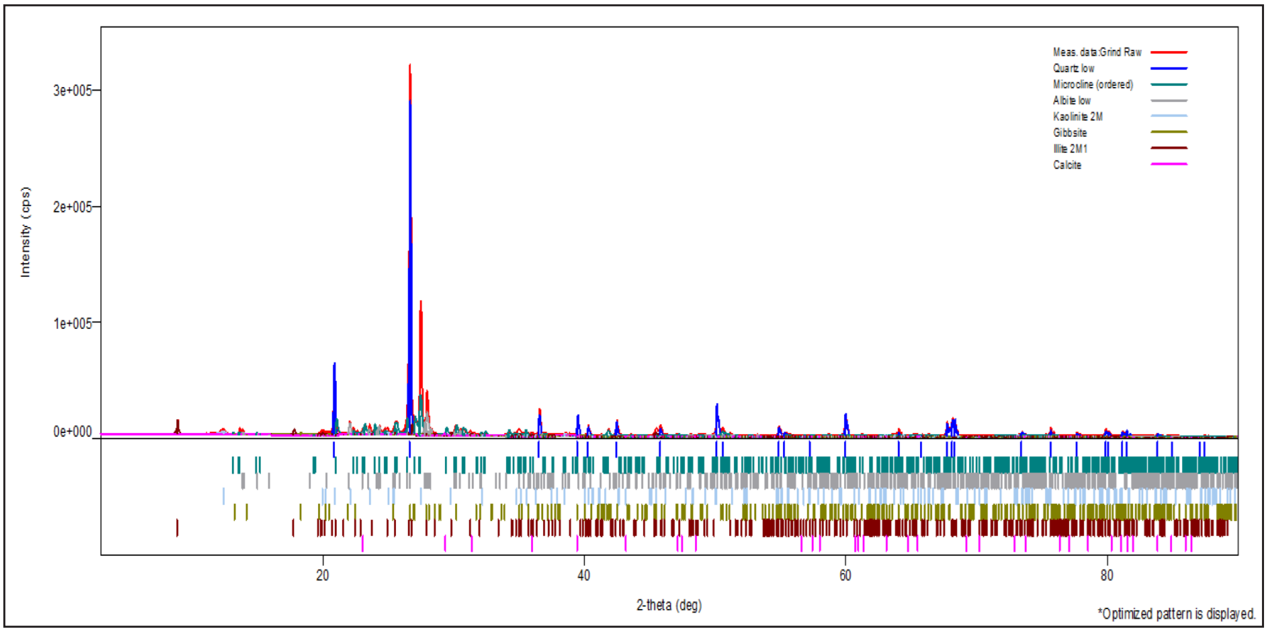
APPENDIX A (i): Raw sample XRD Data



APPENDIX A (ii): Grind sample XRD Data



APPENDIX A (iii): Sieve sample XRD Data



APPENDIX B: ICP MS concentration table in PPM unit.

Sample Name	SAMPLE A	SAMPLE B	SAMPLE C
Sc	1.0	1.4	1.0
Y	1295.4	1799.2	1152.0
La	2778.6	3853.1	2410.5
Ce	233.7	366.8	205.1
Pr	784.1	1107.6	686.4
Nd	2854.0	4000.0	2489.3
Sm	680.0	953.4	593.6
Eu	22.3	30.6	18.3
Gd	448.9	630.3	391.7
Tb	69.8	97.0	61.7
Dy	352.9	493.0	317.4
Ho	54.2	73.6	45.4
Er	140.1	185.5	119.2
Tm	17.8	24.5	16.3
Yb	105.2	156.1	92.0
Lu	13.0	17.5	11.1

APPENDIX C: Relative Enrichment

Sample Name	Enrichment B (%)	Enrichment C (%)
Sc	143.0	100.0
Y	138.9	88.9
La	138.7	86.8
Ce	157.0	87.7
Pr	141.3	87.5
Nd	140.2	87.2
Sm	140.2	87.3
Eu	137.3	81.9
Gd	140.4	87.3
Tb	139.0	88.5
Dy	139.7	89.9
Ho	135.7	83.7
Er	132.4	85.1
Tm	137.6	92.0
Yb	148.4	87.5
Lu	134.7	85.8

APPENDIX D: Element Mass

Sample Name	Total A (mg)	Total B (mg)	Total C (mg)
Sc	3.0	2.4	2.9
Y	3886.3	2968.6	3363.8
La	8335.9	6357.6	7038.7
Ce	701.2	605.3	598.8
Pr	2352.2	1827.5	2004.3
Nd	8562.1	6600.1	7268.7
Sm	2040.0	1573.1	1733.2
Eu	67.0	50.6	53.4
Gd	1346.6	1040.0	1143.9
Tb	209.3	160.0	180.3
Dy	1058.8	813.4	926.9
Ho	162.6	121.4	132.5
Er	420.4	306.1	348.2
Tm	53.3	40.3	47.7
Yb	315.6	257.6	268.7
Lu	38.9	28.9	32.5

APPENDIX E: Total Recovery

Sample Name	Recovery B (%)	Recovery C (%)
Sc	78.7	97.3
Y	76.4	86.6
La	76.3	84.4
Ce	86.3	85.4
Pr	77.7	85.2
Nd	77.1	84.9
Sm	77.1	85.0
Eu	75.5	79.7
Gd	77.2	84.9
Tb	76.5	86.1
Dy	76.8	87.5
Ho	74.6	81.5
Er	72.8	82.8
Tm	75.7	89.5
Yb	81.6	85.1
Lu	74.1	83.5

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PERSATUAN GEOLOGI MALAYSIA
GEOLOGICAL SOCIETY OF MALAYSIA

59th ANNUAL GENERAL MEETING & ANNUAL REPORT 2024

25th April 2025
Geology Department, University of Malaya, Kuala Lumpur

Agenda

The Agenda for the Annual General Meeting is as follows:

1. Welcoming Address by the President for Session 2024/2025
2. Adoption of Agenda
3. Confirmation of Minutes of the 58th AGM held on the 23rd April 2024
4. Matters Arising
5. Annual Report for Session 2024/2025
   - President's Report
   - Secretary's Report
   - Editor's Report
   - Treasurer's and Honorary Auditor's Reports
   - GSM Endowment Fund Report
6. Election of Honorary Auditor
7. Other Matters
   7.1 N.S. Haile Publication Award/Young Geoscientist Award
   This award to stimulate and encourage young geoscientists to publish their findings was mooted by Prof. N.S. Haile, of the Department of Geology, University of Malaya in 1978.
   Proposal for the sum of RM1000 donation by Haile in 1978, to be absorbed into the GSM Endowment Fund – The Treasurer
   7.2 "Shifting away from business as usual: exploring opportunities that put the geosciences profession in the forefront of climate challenges"- Danny Soo
8. Announcement of New Council for 2025/2026
9. Presidential Address for 2025/2026

Please note that no other matters shall be discussed, unless prior written notice is received by the **18th April 2025** or by majority vote of the Annual General Meeting. This is in accordance to the Article VII, Section 4 of the Constitution.

Confirmation of Minutes of the 58th AGM

PERSATUAN GEOLOGI MALAYSIA
GEOLOGICAL SOCIETY OF MALAYSIA (GSM)

MINUTES OF 58th ANNUAL GENERAL MEETING

Date: 23rd April 2024
Time: 5.30 p.m.
Venue/Platform: PAUM Clubhouse, University of Malaya, Kuala Lumpur

Members' Attendance: Appendix 1

1. Welcoming Address by the President for Session 2023/2024

Mohd Hariri Arifin, the President of Geological Society of Malaysia acted as the Chairperson of the AGM and called the meeting to order at 5.32pm. He commended the overwhelming response of the members to the AGM and started the meeting by paying tribute to the late Ahmad Said Fasal Mohammed, a past GSM President who passed away on 22 April 2024.

2. Adoption of Agenda

The following amended agenda was accepted by the AGM:

1. Welcoming Address by the President for Session 2023/2024
2. Adoption of Agenda
3. Confirmation of Minutes of the 57th AGM held on the 28th April 2023
4. Matters arising
5. Annual Report for Session 2023/2024
   - President's Report
   - Secretary's Report
   - Editor's Report
   - Treasurer's and Honorary Auditor's Reports
   - GSM Endowment Fund Report
6. Election of Honorary Auditor
7. Other Matters (By majority vote of AGM):
   – Waiver of registration fee for National Geoscience Conference by Askury Abd. Kadir (There was no written notice received by the Secretariat by the 15th April 2024)
8. Announcement of New Council for 2024/2025
9. Presidential Address

3. Confirmation of Minutes of the previous AGM

The Minutes of the 57th AGM was tabled for confirmation.
Mohd Badzran Mat Taib proposed that the minutes be confirmed, which was seconded by Lim Choun Sian.

The minutes were unanimously confirmed without any amendment.

4. Matters Arising

4.1 GSM Working Groups

Arnout J.W. Everts suggested the GSM Working Groups formed should reflect the current geoscience scenario encompassing the current interest and the growing expectation of the society.
He proposed the formation of a new group "Environmental Geology and Climate Change".

Action: Incoming Council

5. **Annual Reports 2023/2024**

5.1 President's Report

Mohd Hariri Arifin tabled the President's Report (As in the 58th AGM Proceedings).

The AGM discussed the followings:

5.1.1 Publication of "CEO GEO"

The President proposed a new GSM book project - 'CEO GEO' with the objective of sharing the experiences and knowledge from leaders in the geoscience industries to inspire young geologists in their profession.

The AGM discussed the matter and preferred a book of this nature to be published by IGM because the role of IGM is to promote professional development.

Alternatively, GSM could select a few CEOs and publish their stories in Warta, with the CEOs advertising their respective companies in Warta.

5.1.2 Publication of "Kamus Istilah Geologi"

The AGM welcomed the proposal and suggested a committee should be formed to that effect.

Lim Choun Sian proposed to include "Disaster and Climate" page and the publication to be in the format similar to Wikipedia format that allows constant updating.

Action: Incoming Council

Yunus Abd Razak proposed that the President's Report be accepted and this was seconded by Arnout J.W. Everts.

5.2 Secretary's Report

Ling Nan Ley tabled the Secretary's Report (As in the 58th AGM Proceedings).

The AGM discussed the followings:

5.2.1 Claim for attending Council meeting

Mohd Hariri Arifin urged that since there was a decision in the past on paying honorarium to the Council members for attending Council Meetings, GSM should pay to the Council members accordingly.

Lim Choun Sian clarified that the decision made was that each member could claim up to a maximum of RM 100 for attending each meeting, but so far no one has made any claim.

The AGM discussed the matter and viewed that GSM is a learned society and all should serve the society voluntarily without expecting any return.

Information

5.2.2 Promotion of Geoscience knowledge to the society/public

Ibrahim Komoo proposed that GSM's role should change, instead of only building up geological knowledge among the members, GSM should reach out to the general public, promoting the contribution of geoscience for the welfare of the public.

Action: Incoming Council

Tan Boon Kong proposed that the Secretary's Report be accepted and this was seconded by Fateh Chand.

5.3 Editor's Report

Joy Jacqueline Pereira tabled the Editor's Report (As in the 58th AGM Proceedings).

No comment was raised at the meeting concerning this report.

Fateh Chand proposed that the Editor's Report be accepted and Azimah Ali seconded.

5.4 Treasurer's and Honorary Auditor's Report

Lim Choun Sian tabled the Treasurer's and Honorary Auditor's Report (As in the 58th AGM Proceedings).

The AGM discussed the following matters:

5.4.1 GSM Student Chapters

Tan Boon Kong opined that the main criteria for approving fund to GSM Student Chapter is that the activity content must be on geology.

The meeting proposed an SOP or guideline should be set in place for approving any funding request from the Student Chapters.

Action: Incoming Council

Yunus Abd Razak proposed that the Treasurer's and Honorary Auditor's Report be accepted and this was seconded by Joy Jacqueline Pereira.

5.5 GSM Endowment Fund's Report

Yunus Abd Razak, as the Chairman of Board of Trustees of the GSM Endowment Fund, tabled the GSM Endowment Fund report (As in the 58th AGM Proceedings).

The Board of Trustees made 3 recommendations to the 58th AGM as follows:
(i) The GSM Council is requested to report progress to the Board of Trustees of the GSM Endowment Fund regarding implementation of the proposed modality for using accumulated interest earned (RM 14,946.16 as of 31 December 2023) from the donation of RM 50,000.00 by YBhg. Dato' Sia Hok Kiang to the GSM Endowment Fund in 2014.
(ii) The AGM is recommended to approve the sum of RM 40,000.00 that is requested by the GSM Council for the publications for the year 2024. The GSM Council is requested to report the usage of the fund to the Board of Trustees of the GSM Endowment Fund.
(iii) The AGM is recommended to approve the maximum sum of RM 24,000.00 that is requested by the NGC 2024 Organizing Committee to subsidize the registration fees of GSM student members only.

The AGM accepted all the 3 recommendations above and the Incoming Council ought to carry out the recommendations diligently.

Action: Incoming Council

Adam Hashim proposed that the GSM Endowment Fund's Report be accepted and Nicholas Jacob seconded the proposal.

6. Election of Honorary Auditor

Lim Choun Sian proposed to continue appointing S.F. Lee & Co as the Honorary Auditor for the year 2024. The AGM unanimously agreed to the appointment.

7. Other Matters

(By majority vote of AGM):

<u>1. Waiver of registration fee for National Geoscience Conference (NGC)</u>
Askury Abd. Kadir proposed the followings:
(i) 100% waiver of registration fee for GSM members above 60 years old, who present papers in NGC;
(ii) 50% discount of registration fee for GSM members aged above 60;
(iii) Free for Honorary and Life Members above 60 years old to attend NGC.

The AGM rejected proposal (iii) above.
The AGM proposed the Incoming Council to look into the proposal (i) and (ii) and to bring up the Council's view to the next AGM for decision.

Action: Incoming Council

8. Announcement of New Council for 2024/2025

Muhammad Hatta Roselee, the Chairman of the Nominations Committee presented the nomination/election report (As in the 58th AGM Proceedings) and thereafter, announced the Council for 2024/2025.

President	:	Associate Prof. Ts Dr Mohd Hariri Arifin, P.Geol. (UKM)
Vice-President	:	Associate Prof. Dr Meor Hakif Amir Hassan, P.Geol. (UM)
Imm. Past President	:	Ahmad Nizam Hasan (GeoSolution Resources)
Secretary	:	Ling Nan Ley, P.Geol.
Assistant Secretary	:	Norazianti Asmari, P.Geol. (GeoExpert)
Treasurer	:	Dr. Lim Choun Sian, P.Geol. (UKM)
Editor	:	Prof. Dr. Joy Jacqueline Pereira, P.Geol. (UKM)
Councillors (2 years)	:	Dr. Allagu Balaguru (Freelance Consultant)
		Muhammad Ashahadi Dzulkafli, P.Geol. (UKM)
		Muhammad Azri Ismail, P.Geol.(JMG)
		Tan Boon Kong

Councillors (1 year) : Cindy Simba Ngumbang, P.Geol. (Sabah Shell Petroleum Company Limited)
Mohd Shafiq Firdaus Abdul Razak (Beicip-Franlab Asia)
Dr. Muhammad Hatta Roselee, P.Geol. (UM)
Dr. Siti Nur Fathiyah Jamaludin, P.Geol. (UTP)

9. Presidential Address

The re-elected President Mohd Hariri Arifin expressed that it is a great honour for him to be elected to serve as the President and thanked the members for their support and confidence. He informed the AGM that this was going to be his last term as the President and pledged that he and the new Council would devote themselves to the service of GSM and the members. He hoped to see GSM to be more friendly to the younger geologists.

The President recorded a vote of thanks to the out-going Council. The AGM was adjourned at 7:00 pm.

LING NAN LEY
Secretary 2023/2024

Appendix 1: Members' Attendance

1	Abdul Hadi Abd Rahman	18	Meor Hakif Amir Hassan
2	Abdull Halim Abdul	19	Mirza Arshad Beg
3	Ahmad Farid Abu Bakar	20	Mohd Badzran Mat Taib
4	Ahmad Fauzi @ Adam Hashim	21	Mohd Hariri Arifin
5	Allagu Balaguru	22	Muhammad Hatta Roselee
6	Arnout J.W. Everts	23	Nicholas Jacob
7	Askury Abd. Kadir	24	Nor Shahidah Mohd Nazer
8	Azimah Ali	25	Nur Iskandar Taib
9	Cheah Gim Hoe, Calvin	26	Ros Fatihah
10	Fateh Chand	27	Tan Boon Kong
11	Ibrahim Komoo	28	Tan Zhi Mian, Irving
12	Jaideep Bose	29	Wan Hasiah Abdullah
13	Joy Jacqueline Pereira	30	Wan Mohamed Nizam Wan Isa
14	Lee Chai Peng	31	Yip Foo Weng
15	Lim Choun Sian	32	Yunus Abd Razak
16	Ling Nan Ley	33	Zuhar Zahir Tuan Harith
17	Lutfi Hamidee Abd. Latif		-------------

Total number of members present at the AGM: 33

Annual Report for Session 2024/2025

President's Report

Introduction

I extend my heartfelt thanks to all Council members and the Secretariat for their unwavering support, and to all GSM members attending this AGM for the 2024/2025 session.

Programmes and Collaborations

This session, we conducted a total of 49 activities, slightly fewer than the 54 activities in the previous session. Perhaps setting a benchmark of 50 activities for the new Council lineup is a reasonable target!

Over the past year, GSM organized 26 activities, compared to 33 in the last session. The remaining activities were collaborative efforts with esteemed institutions, including the Institute of Geology Malaysia (IGM), Board of Geologists Malaysia (BoG), Department of Mineral and Geoscience Malaysia (JMG), University of Malaya (UM), Universiti Kebangsaan Malaysia (UKM), Universiti Malaysia Terengganu (UMT), Universiti Teknologi PETRONAS (UTP), Universiti Sains Malaysia (USM), Universiti Malaysia Kelantan (UMK), and Universiti Malaysia Pahang Al-Sultan Abdullah (UMPSA).

Our student chapters also made significant contributions, with the Universiti Malaysia Sabah (GSM-UMS SC) standing out as the most active club. I would also like to acknowledge the contributions of Academy GEX from GeoXpert Sdn Bhd and Digital Geoscience Global Sdn Bhd (DGEG), who consistently support our training programs and field trips. Special thanks to all parties involved, including those not mentioned individually here. The Chairs of our Working Groups also deserve recognition for their invaluable assistance.

NGC 2024, 2025, and Looking Ahead to NGC 2026

Dear esteemed members,

I extend my heartfelt gratitude for your unwavering support throughout 2024. The past year has been marked by significant achievements, notably the success of NGC 2024, which generated approximately RM60,000 in revenue. The event was led by Assoc. Prof. Dr. Meor Hakif Amir Hassan, our Vice President at the time and, God willing, the incoming President for the next session. The Department of Geology provided full support for this event, which was attended by around 200 participants and held at the Wyndham Grand Bangsar, Kuala Lumpur, from 1–2 October 2024. A field trip to the Bukit Takun karst area, led by Dr. Ros Fatihah Muhammad, followed the conference.

GSM is pleased to announce that the 38th National Geoscience Conference (NGC 2025) will be held from 18 to 20 September 2025 at the Royale Borneo Hotel in Tawau, Sabah. This event is co-organized with Universiti Malaysia Sabah (UMS) and the Department of Minerals and Geoscience Malaysia (JMG) Sabah, in collaboration with the Board of Geologists (BoG) and the Institute of Geology Malaysia (IGM). The conference theme, "Earth, Energy, and Environment: Navigating the Future," underscores the importance of geosciences in addressing contemporary challenges. Tawau offers unique geological features, including gold deposits, columnar basalt formations, and geothermal resources. I hope everyone can join us for this exciting event.

Looking ahead, we are now inviting proposals to host the 39th National Geoscience Conference (NGC 2026). This is an excellent opportunity for institutions, universities, or organizations to showcase their commitment to advancing geosciences in Malaysia. Interested parties are encouraged to submit their proposals to the GSM Secretariat by 31 May 2025. We look forward to receiving your innovative ideas and hosting plans.

Additionally, the 19th GEOSEA will be chaired by Indonesia, led by Ikatan Ahli Geologi Indonesia (IAGI), and is scheduled to be held at the end of October 2026 in Yogyakarta.

Publications: 'CEO GEO' Book and Illustrated Geological Terminology Dictionary
I would like to apologize for the delay in progressing the new GSM book project, 'CEO GEO,' and the illustrated Geological Terminology Dictionary. Both projects are currently pending due to the demanding schedules of myself and Mr. Rasid. We have agreed to serve as editors for the 'CEO GEO' book, which aims to share the experiences and knowledge of leaders in the geoscience industry to inspire young geoscientists in their professional journeys.

After concluding my term as President, I anticipate having more time to focus on these projects. As for the Geological Terminology Dictionary, it remains pending. I make a renewed commitment to focus on this project in 2026, which will require collaboration with Dewan Bahasa dan Pustaka (DBP). Dr. Suraya from Universiti Kebangsaan Malaysia (UKM) will work closely with me to finalize the committee members for this dictionary.

GSM Dato' Sia Endowment Fund for Economic Mineral Research
I am pleased to highlight the GSM Dato' Sia Endowment Fund, established through a generous RM50,000 donation by YBhg. Dato' Sia Hok Kiang in 2014. The interest accrued from this fund is designated to support research in economic mineral exploration and development. As of the end of 2024, the accumulated interest stands at RM16,483.70. The GSM Council is committed to managing these funds responsibly to advance mineral research initiatives. Members interested in applying for research support from this fund are encouraged to submit their proposals to the GSM Secretariat.

Closing Remarks
In the years to come, I hope that GSM will become more established and receive widespread recognition through the contributions and support of its members. GSM serves as a platform to nurture both young and experienced professionals, creating a vibrant community and support network within the geological field. We are enthusiastic about welcoming new members from various backgrounds, including fresh graduates and seasoned professionals. I encourage you to consider joining us as part of the Council.

For me, GSM cannot continue with business as usual. To attract the new generation, believe me, we need to evolve and become more youth-friendly!

Thank you.

Assoc. Prof. P. Geol. Ts. Dr. Mohd Hariri Arifin
President 2024/2025
Geological Society of Malaysia

Secretary's Report

1.0 Introduction

On behalf of the members of the Council of the Geological Society of Malaysia (GSM), it is my pleasure to present the Secretary's Report for the session 2024/2025.

2.0 Society structure

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

The Council is supported by 11 Geoscience Working Groups and 5 Promotion/Supporting Working Groups. The Geoscience Working Groups' main function is to promote the advancement and exchange of knowledge in specific geoscience areas whereas the role of the Promotion/Supporting Working Groups is to promote the publicity of the society and to support the running of the Council.

The Council is assisted by the Secretariat in the administration of the day-to-day activities of the Society.

3.0 Membership

The table below presents the details of membership categories and their geographical breakdown (based on the members' mailing addresses).

As of 31st December 2024, the total number of registered members in the Society stood at 1158. There was an overall membership increase of 43 members when compared to the year 2023. The increases were in the Life and Full Membership categories, all were from Malaysia. The membership from other countries was only a handful, almost all were of Life Membership category, and was seen on a slight diminishing trend.

Breakdown of Membership

COUNTRY	Hon.	Life	Full	Assoc.	Student	Total 2024	Total 2023	Variance (2024-2023)
Malaysia	11	481	131	8	441	**1072**	**1024**	**+48**
Australia	1	19	-	-	-	**20**	**21**	**-1**
Bangladesh		2				**2**	**2**	**0**
Brunei		1				**1**	**2**	**-1**
Canada	-	2	-	-	-	**2**	**3**	**-1**
China	-	1	-	-	-	**1**	**1**	**0**
Europe	-	14	-	-	-	**14**	**16**	**-2**
Hong Kong	-	1	-	-	-	**1**	**1**	**0**
India		2				**2**	**3**	**-1**
Indonesia	-	9	-	-	-	**9**	**9**	**0**
Japan	-	2	-	-	-	**2**	**3**	**-1**
Libya		4				**4**	**3**	**+1**
New Zealand		2				**2**	**2**	**0**
Nigeria		1				**1**	**-**	**+1**
Philippines		2	-	-	-	**2**	**2**	**0**
Qatar		1	-	-	-	**1**	**1**	**0**
Singapore		9	-	-	-	**9**	**9**	**0**
Thailand		2	-	-	-	**2**	**2**	**0**
USA		11	-	-	-	**11**	**11**	**0**
TOTAL 2024	**12**	**566**	**131**	**8**	**441**	**1158**		
TOTAL 2023	**12**	**552**	**94**	**9**	**448**		**1115**	
Variance (2024-023)	**0**	**+14**	**+37**	**-1**	**-7**			

4.0 The Council

The Council for the Geological Society of Malaysia (GSM) for 2024/2025 session resumed their office after the 58th AGM on the 23rd April 2024.

4.1 Council Members

The Council Members for 2024/2025 are as follows:

President:	Dr. Mohd Hariri Arifin
Vice President:	Dr. Meor Hakif Amir Hassan
Immediate Past President:	Mr. Ahmad Nizam Hasan
Secretary:	Mr. Ling Nan Ley
Assistant Secretary:	Ms. Norazianti Asmari
Treasurer:	Dr. Lim Choun Sian
Editor:	Prof. Dr. Joy Jacqueline Pereira
Councillors:	
(2024/2025)	Ms. Cindy Simba Ngumbang
	Mr. Mohd Shafiq Firdaus Abdul Razak
	Dr. Muhammad Hatta Roselee
	Dr. Siti Nur Fathiyah Jamaludin
(2024/2025 - 2025/2026)	Dr. Allagu Balaguru
	Muhammad Ashahadi Dzulkafli
	Muhammad Azri Ismail
	Tan Boon Kong

4.2 Council Meetings

During the 2024/2025 session, the Council met 5 times. The attendance of the meetings is presented table below. Except for the first Council Meeting which was held at the meeting room of the Department of Geology, University of Malaya, Kuala Lumpur, all the other meetings were conducted online.

Attendance of Council Members to the Council Meetings

NAME	17/5/24 (UM)	13/8/24	16/12/24	4/2/25	25/3/25	Total
Mohd Hariri Arifin	/	/	/	/	/	5/5
Meor Hakif Amir Hassan	/	/	/	/	/	5/5
Ling Nan Ley	/	/	/	/	/	5/5
Norazianti Asmari	0	/	/	0	/	3/5
Lim Choun Sian	/	/	/	/	/	5/5
Joy Jacqueline Pereira	/	/	/	/	/	5/5
Ahmad Nizam Hassan - IPP	0	0	0	0	0	0/5
Cindy Simba Ngumbang	0	0	0	0	0	0/5
M. Shafiq Firdauz Abdul Razak	/	/	0	/	0	3/5
Muhammad Hatta Roselee	/	/	/	/	0	4/5
Siti Nur Fathiyah Jamaludin	/	/	0	/	/	4/5
Allagu Balaguru	/	/	0	/	0	3/5
Muhammad Ashahadi Dzulkafli	/	/	0	0	/	3/5
Muhammad Azri Ismail	/	0	0	0	0	1/5
Tan Boon Kong	/	/	/	/	/	5/5

Note: / = present 0 = absent with apologies

5.0 Working Groups

The Working Groups and the Chairs for Session 2024/2025 are as follows:

	A. GEOSCIENCE WORKING GROUP	CHAIRMAN
1	Engineering Geology & Environmental Geology	Mr. Tan Boon Kong
2	Hydrogeology	Mr. Adam Hashim
3	Economic Geology & Mineral Resources	Dr. Zakaria Endut
4	Regional Geology & Stratigraphy	Dr. Meor Hakif Amir Hassan
5	Geophysics	Dr. Siti Nur Fathiyah
6	Petroleum Geoscience & Energy Transition	Dr. Allagu Balaguru
7	Offshore Hazards and HSE	Ms. Cindy Simba Ngumbang
8	Quaternary & Marine Geology	Dr. Khaira Ismail
9	Disaster Risk Reduction & Climate Change	Prof Dr. Joy Jacqueline Pereira
10	Geological Heritage	Mr. M. Ashahadi Dzulkafli
11	Karst & Caves	Dr. Ros Fatihah

	B. PROMOTION/SUPPORTING WORKING GROUP	CHAIRMAN
1	Membership Database	Dr. Muhammad Hatta Roselee
2	Promotion of Geoscience, Social Media & Digital Content	Ms. Norazianti Asmari
3	Young Geologist & Student Outreach	Dr. Muhammad Hatta Roselee
4	IT & Website	Dr. Lim Choun Sian Ms. Norazianti Asmari Mr. Muhammad Azri Ismail
5	CPD - Liason with BoG	Ms. Norazianti Asmari

6.0 Activities

The Society had successfully organised activities such as technical talks, field visit and short courses.

6.1 Activities organised by GSM

During the session, the Council, mainly through the Chairs of Working Groups, were able to organise a total of 26 activities.

Summary of activities organized by GSM.

No	Date	Title	Speaker	Collaborator	Attendance	CPD
1	2.5.2024	Cutting-edge Techniques in Advanced Resource Estimation: Innovations, Challenges, and Future Prospects	Dr. Nasser Madani	USM	64	Yes (1 CPD)
2	15.5.2024	Karst and caves of Australia	Mr. Ramli Osman	IGM, UM	70	
3	15.5.2024	Seismic Applications in Industry and Sustainability	Dr. Mohamed Abdelghany Mahgoub	UTP	97	

No	Date	Title	Speaker	Collaborator	Attendance	CPD
4	4.6.2024	Application of Hydro-chemical Traces, as a Tool in Hydrogeology	Ms. Konstantina Katsanou	IGM	50	Yes (1 CPD)
5	12.6.2024	Sustainable Groundwater Development	Datuk Ir. P. Geol. Dr. Azuhan Mohamed	IGM, UM	100	
6	10.7.2024	Training on Seismic Reflection Data Acquisition and Processing	Demonstrator: Abdul Rahim Md Arshad Facilitator: Ahmad Dedi Putra Trainer: Amir Mustaqim Majdi, Amirul Qhalis Abu Rashid, Dr. Alidu Rashid, P. Geol. Ts. Dr. Muhammad Noor Amin Zakariah, M. Najib Termizi Speaker: Dr. Ismailalwali Alobaid Magzoub Babikir, Hazwan Syahmi Hashim	Centre of Subsurface Imaging UTP, GSM-UTP Student Chapter	35	
7	12.7.2024	Silicate Weathering Versus Reverse Weathering Across Geological Time	Prof. Dr. Santanu Banerjee	UM	33	
8	17.7.2024	Landslide Forensic Investigation: Approach, Practice and Case Studies in Malaysia	P.Geol. Abdul Rasid Jaapar	IGM, UM	100	
9	26.7.2024	Satellite Geodesy Applications on Tectonic Deformation	Mr. Chong Jeng Hann	UM	45	
10	21.8.2024	The influence of lithology on pipe jacking through the Tuang Formation in Kuching	Ir. Dr. Choo Chung Siung	IGM, UM	60	
11	11.9.2024	Pelan Induk Cerun Negara / National Slope Master Plan	Ir. Nursalbiah Binti Hamidun	IGM, UM	100	
12	11.9.2024	Advancing Mining Practices through Innovative Solutions	Kenneze Santic	MAWEA Industries Sdn Bhd, Dassault Systemes, UM	70	Yes (2 CPD)
13	18.9.2024	Taklimat Kepentingan berdaftar dengan Lembaga Ahli Geologi Malaysia (BoG) & Aktif dalam satuan Geologi Malaysia (GSM) & Institut Geologi Malaysia (IGM)	P. Geol. Dr. Mohd Hariri Arifin, P. Geol. Adam Hashim, P. Geol. Mohd Badzran Mat Taib	IGM, BOG, UMK	31	

No	Date	Title	Speaker	Collaborator	Attendance	CPD
14	1-2.10.2024	National Geoscience Conference (NGC) 2024, Wyndham Grand Bangsar, KL		UM	246	Yes (4 CPD)
15	3.10.2025	Post- Conference Fieldtrip NGC 2024- Introduction to Karst	Dr. Ros Fatihah	UM	20	Yes (3 CPD)
16	9.10.2024	Challenges in Design and Construction of MRT Underground Station in Kuala Lumpur Limestone	Ir Tan Yean Chin	IGM, UM	100	
17	20.11.2024	Geological and Geotechnical Problems in Construction in Sarawak	P. Geol. James anak Bachat	IGM, UM	100	
18	22.11.2024	Carbon Sequestration in Conventional and Unconventional Hydrocarbon Field	Dr. Nimisha Vedanti (CSIR- National Geophysical Research Institute, India)	UM	117	Yes (1 CPD)
19	18.12.2024	Fracture Mapping using Photogrammetry Method	Ir. P. Geol. Dr. Goh Thian Lai	IGM, UM	80	
20	15.1.2025	Penyerakan dan Pengasingan Tanah Baki sebagai Mekanisme Utama Hakisan Dalaman dan Permukaan serta Pengaruhnya sebagai Faktor Pengawal Tanah Runtuh	Sdr. Azlan Shah Nerwan Shah (UKM)	IGM, UM	55	
21	12.2.2025	Geotechnical BIM & Digital Twins	Ir. Dr. Gue Chang Shin (G&P)	IGM, UM	100	
22	24-28.2.2025	Geophysics Week @UTP		Centre of Subsurface Imaging UTP, GSM-UTP Student Chapter	30	
23	12.3.2025	Geotechnical Observations on Pile Behaviour in Negative Face Loss Tunnelling: Risks and Opportunities	Ir. Dr. Khoo Chee Min (CMKS Consultancy Sdn Bhd)	IGM, UM	100	
24	17.3.2025	3D (Three- Dimensional) Geological Mapping Using Electromagnetics (GEm)	Mr. Rex Camit & Dr. Emmanuel Ramos	IGM, UKM	100	
25	17.4.2025	Quantification of sedimentation and diagenesis in tectonic settings	Prof. Dr. Liviu C. Matenco (Department of Earth Sciences, Faculty of Geosciences, Utrecht University)	UM	117	
26	23.4.2025	Geological Evaluation Study of Batu Arang, Gombak from GeoHeritage to GeoHazard	P. Geol. Ahmad Nizam Hasan (Geosolution Resources)	IGM, UM	137	

6.2 Activities organised by GSM

GSM collaborated in 23 other activities organized by various other institutions.

Summary of collaboration in other activities organized by the other institutions.

No	Date	Title	Speaker	Organiser	Collaborator
1	24.4.2024	Geology Technical Talk Series 3/2024: The Role of Groundwater Monitoring Network in Coastal Groundwater Management and Optimization Strategy	Mr. Dewandra Bagus Eka Putra	UKM	GSM, IGM
2	15.5.2024	1- The Quaternary Geology of Peninsular Malaysia and The Straits of Malacca	Dr. Habibah binti Jamil	UKM	GSM, IGM
		2- Geological Character of Sumatera (Indonesia) and Malaysia: Its Impact on Both Nations	Prof. Dr. Yahdi Zaim, IPU		
3	14-16.5.2024	Geology Museum Open Day 2024: Bridging the gap with society		UM	GSM, UM-AAPG, UM-EAGE
4	23.5.2024	Online Webinar Technical Series 06/2024-Powering the Future: Geothermal Energy in Malaysia	Dr. Mohd Hariri Arifin/ Mohammad Noor Akmal Anuar	IGM	Digital Geoscience Global Sdn Bhd (DGEG)/GTR/GSM
5	12.6.2024	Geology Technical Talk Series 5/2024: Geologist Career Prospect in Engineering and Construction Industry	P. Geol. Fauziah Hanis	UKM	GSM, IGM
6	26-28.6.2024	Tech-In-Geo: Paleoscan - Upskilling programme	Najiatun Najla, Nabilah Mohamed Zainuddin, Nurbalqis Azfaruddin	UMS/ Eliis	GSM
7	14.7.2024	Late Paleozoic Clastic Deposition & Compressional Tectonics on Sibumasu: A One Field Excursion from Kuala Lumpur	Allan Filipov and Robert Shoup	RCS	Kuala Lumpur Geoscience Group, GSM
8	12.9.2024	Fenomena Sinkhole	Dr. Mohd Hariri Arifin, Ustaz Wan Jemizan W Deraman, En Ahmad Fariman Yunus	UKM	GSM, Takaful Ikhlas
9	23-25.9.2024	Malaysia International Geothermal Conference (MIGC)		UKM	GSM
10	3.10.2024	Seminar: Nurturing an Eco-Mining Practice for Sustainable Mining in Malaysia		UMPSA Advanced	Akademi Mineral Malaysia Pahang, GSM

No	Date	Title	Speaker	Organiser	Collaborator
11	20.10.2024	Current issues on geomorphology in Malaysia and Indonesia: IAG-Malaysia Webinar Recap	Prof. Rodeano Roslee, Dr. Ros Fatihah Muhammad, Alfend Rudyawan, Dr. Elvaene James and Dr. Edlic Sathiamurthy	International Association of Geomorphologists (IAG) – National Scientific Member (NSM) and UMT	GSM
12	6.11.2024	Graptolites research in Malaysia: from its uses in biostratigraphy to the paleoenvironment and thermal maturities studies	Dr. Muhammad Aqqid bin Saparin (Nanjing Institute if Geology and Paleontology, Chinese Academy of Sciences (NIGPAS)	UKM	GSM, IGM
13	25.11.2024	Analysis of Rare Earth Elements (REE) in Granite and Sandstone & Chloride Analysis in Rare Earth Samples	Ms. Chawanrut Wattanawiboon (Analytik Jena Instruments (Thailand) Ltd.) and Mr. Thnaraj Ravichandran (Lab Science Solution Sdn Bhd)	Lab Science Solution Sdn Bhd and Analytik Jena	GSM, UM
14	25.11.2025	MT Array Case Histories for Volcanic, non volcanic and granite targets	Dr. Wen J. Whan (3JTech Co. Ltd)	IGM, DGEG	GSM
15	26.11.2025	Geothermal Energy, Malaysia's Potential and Primeval Energy Case Studies in Brown and Green Field Environments	Andy Wood (Primeval Energy Ltd)	IGM, DGEG	GSM
16	27.11.2024	Rig and Equipment Specifications for Geothermal Slim Hole Coring	Ir. Hendy Purwa Madya (Planetary Drilling Indonesia)	IGM, DGEG	GSM
17	29.11.2024	Geothermal Week: Technical Talk Series- Enhanced Geothermal Systems: New Developments	Prof. Dr. D. Chandrasekharam	IGM, DGEG	GSM
18	18.12.2024	Menghubungkan Akademik dan Industri: Menerapkan Pengetahuan Geologi dari UKM ke Eksplorasi Dunia Sebenar	Pn. Rafeeqa binti Ab Rashid (Geosaintis Kanan, PETRONAS Carigali Sdn Bhd)	UKM	GSM, IGM
19	19.12.2024	Geothermal Applications and Career Opportunities	Geothermal Applications and Career Opportunities	UKM	GSM, IGM

No	Date	Title	Speaker	Organiser	Collaborator
20	8.1.2025	Introduction to Submarines and The Underwater Environment	Komander Ir. Shahriman bin Shawaluddin TLDM (Bersara)	UKM	GSM, IGM
21	15.1.2025	Marine Geohazards	Muhd Akram Kamaruzaman (Sarawak Shell Berhad)	UKM	GSM, IGM
22	25.1.2025	Kembara Formasi : Formasi Kenny Hill	Dr. Azhar Hussin, P. Geol. Norazianti Asmari, P. Geol. Mohd Shaufi Sokiman	Academy GEX	GSM, GeoExpert
23	14.3.2025	Technical Talk: Road to EIA Subject Specialist	Puan Rohimah Ayub (JAS)	UKM	GSM, IGM

7.0 National Geoscience Conference

7.1 The National Geoscience Conference 2024 (NGC 2024)

The National Geoscience Conference 2024 (NGC 2024) was successfully held in collaboration with the Department of Geology, Universiti Malaya from the 1 - 3 October 2024 at the Wyndham Grand Bangsar, Kuala Lumpur. The theme of NGC 2024 was “Geoscience for a sustainable future”.

A total of 72 orals and 40 posters were presented. A total of 246 geoscientists from academia as well as the public and private sectors attended the conference. The conference was officially declared open by Datuk P. Geol. Zamri bin Ramli, Director-General of JMG Malaysia.

A total of 20 participants joined the post-conference fieldwork – Introduction to Karst.

7.2 The National Geosience Conference 2025 (NGC 2025)

The National Geoscience Conference 2025 (NGC 2025) will be held in collaboration with the Universiti Malaysia Sabah, from 18-20 September 2025 at the Grand Royale Hotel, Tawau, Sabah. The theme of NGC 2025 is “*Earth, Energy, and Environment: Navigating the Future*”.

8.0 GSM Awards

GSM awarded the GSM HUTCHISON Best Student Award 2024 during NGC 2024. Each award was RM1000.00.

No	Name	University
1	Muhammad Amri bin Mahadir	USM
2	Nur Adliyana bt Hasriman	UKM
3	Hannah Christabel Phua Wen Xuan (RM500) & Muhammad Faheem Nafiz Bin Saberi (RM500)	UM
4	Lim Yan Ying	UMS
5	Kaz Nezhan bin Khalib	UMK
6	Maybelline Kueh Siu Cheng	UTP
7	Mohamad Aqil Azmi Bin Mohd Rasedi	UMT

9.0 Linkages and Collaborations

GSM maintained linkages with national and international institutions such as:

- **Board of Geologists**
  GSM is in close collaboration with BoG and endeavours to streamline its activities in pursuing to achieve the aspiration of BoG Strategic Plan 2040.
  In an effort to promote and advance geoscience knowledge, GSM also organises programmes that award the participants with CPD points.

- **Institute of Geology Malaysia**
  The GSM-IGM Joint Committee, co-chaired by both Presidents was established under the agreement signed on 5th April 2013 by GSM and Institute of Geology Malaysia (IGM).

  During this session, one Joint Committee meeting was held on 18th February 2025. The joint Committee meeting agreed:
  a. To identify and propose new initiatives/joint programmes for implementation and to develop them into flagship/signature programmes of the Joint Committee
  b. To organise Geoscience Education Workshop in 2025
  c. To conduct Programmes for Young Geologists
  d. To jointly pursue the registration of GEOSEA/AFGEO as a society in Malaysia
  e. To work together in implementing the BoG Strategic Plan 2040.

- **GEOSEA/AFGEO**
  a. GSM is the present host of the permanent Secretariat
  b. The country's liaison representatives:
  1. The President of GSM
  2. The President of IGM
  c. Dr. Lim Choun Sian is the Chairman of Malaysia GEOSEA/AFGEO committee

- Confederation of Scientific and Technological Association of Malaysia (COSTAM)
  – GSM is paying subscription to COSTAM

- Formation Evaluation Society Malaysia (FESM)

- American Association of Petroleum Geology (AAPG)

- AAPG Student Chapter of University of Malaya

- Universities
  GSM had signed MoU with the following universities:
  - University of Malaya
  - Universiti Kebangsaan Malaysia
  - Universiti Sains Malaysia
  - Universiti Malaysia Kelantan
  - Universiti Malaysia Terengganu
  - Universiti Malaysia Sabah

10.0 Acknowledgement

The Society would like to record its utmost appreciation to all the individuals and organisations in organising the Society's numerous activities during the session. Special mention must be made of the tremendous support by the Head and staff of the Geology Department, University of Malaya especially in the use of its premises for the Society's meetings and activities. The continued co-operation and support extended by BoG, JMG, IGM, UKM, UTP and UMT is recorded with gratitude. The unwavering support of Ms. Anna Lee and Puan Nazatul Athirah Abdul Khalil – the GSM Secretariat in the administration of GSM is also very much appreciated. Last but not least, the Council also wishes to record its appreciation to all GSM members for their active support and participation throughout the session.

LING NAN LEY
Secretary 2024/2025
Geological Society of Malaysia

Assistant Secretary's Report

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

Sales and stock of publications for 2024 *(Bulletin only)*

Publications	Sales 2024	Stock remaining by end of 2024	Remarks
Bulletin 1	Out of Stock		
Bulletin 2	0	59	
Bulletin 3	0	82	
Bulletin 4	0	68	
Bulletin 5	Out of Stock		
Bulletin 6	0	309	
Bulletin 7	0	215	
Bulletin 8	Out of Stock		
Bulletin 9	Out of Stock		
Bulletin 10	Out of Stock		
Bulletin 11	Out of Stock		
Bulletin 12	Out of Stock		
Bulletin 13	0	5	
Bulletin 14	Out of Stock		
Bulletin 15	Out of Stock		
Bulletin 16	Out of Stock		
Bulletin 17	Out of Stock		
Bulletin 18	Out of Stock		
Bulletin 19	0	313	
Bulletin 20	0	283	
Bulletin 21	0	72	
Bulletin 22	0	151	
Bulletin 23	0	152	
Bulletin 24	0	322	
Bulletin 25	0	109	
Bulletin 26	0	135	
Bulletin 27	0	-	
Bulletin 28	0	88	
Bulletin 29	0	63	
Bulletin 30	0	357	
Bulletin 31	0	52	
Bulletin 32	0	36	
Bulletin 33	0	91	
Bulletin 34	0	18	
Bulletin 35	Out of Stock		
Bulletin 36	0	48	
Bulletin 37	0	186	
Bulletin 38	0	308	

Publication	Sales 2024	Stock remaining by end of 2024	Remarks
Bulletin 39	Out of Stock		
Bulletin 40	0	25	
Bulletin 41	Out of Stock		
Bulletin 42	Out of Stock		
Bulletin 43	0	52	
Bulletin 44	0	-	
Bulletin 45	Out of Stock		
Bulletin 46	Out of Stock		
Bulletin 47	Out of Stock		
Bulletin 48	0	13	
Bulletin 49	0	200	
Bulletin 50	0	315	
Bulletin 51	0	155	
Bulletin 52	0	178	
Bulletin 53	0	211	
Bulletin 54	0	290	
Bulletin 55	0	407	
Bulletin 56	0	136	
Bulletin 57	0	193	
Bulletin 58	Out of Stock		
Bulletin 59	0	14	
Bulletin 60	0	13	
Bulletin 61	0	109	
Bulletin 62	Out of Stock		
Bulletin 63	Out of Stock		
Bulletin 64	Out of Stock		
Bulletin 65	0	93	
Bulletin 66	0	345	
E-Bulletin 67	0	195	
E-Bulletin 68	0	3	
E-Bulletin 69	2	13	
E-Bulletin 70	2	25	
E-Bulletin 71	2	29	
E-Bulletin 72	2	28	
E-Bulletin 73	2	7	Ministry and library
E-Bulletin 74	2	23	
E-Bulletin 75	3	-	
E-Bulletin 76	3	-	
E-Bulletin 77	16	-	
E-Bulletin 78	16	-	

There was a consensus decision made to digitize the Bulletin as of 2019, E-Bulletin 67 onwards, hence only 50 hard printed copies with limited distribution to standing order subscribers.

Sales and stock of publications for 2024 (All other GSM publication)

Other Publications	Sales 2024	Stock remaining by end of 2024
Proceeding AGC 2000	Out of Stock	
Proceeding AGC 2001	0	75
Malaysian Stratigraphic guide	Out of Stock	
Lexicon of stratigraphy	Out of Stock	
Stratigraphic correlation	Out of Stock	
Rocks poster	Out of Stock	
Geology of Borneo (CD)	Out of Stock	
Geology of Borneo (Map)	0	672
Geol. Evolution of SEA	24	276
Geology of P. Malaysia	52	1136

List of organizations and institutions that are exchanging publications with

GSM

Item	Organization	Country
1.	Senckenberg Research Institute and Natural History Museum Frankfurt	Germany

NORAZIANTI ASMARI
Assistant Secretary
Geological Society of Malaysia

Editor's Report

The Geological Society of Malaysia (GSM) has two scientific journals, Bulletin of the Geological Society of Malaysia and Warta Geologi. Two volumes of the Bulletin were published in 2024, Volume 77 (May 2024) and Volume 78 (November 2024). Three issues of Warta Geologi were also published in the same year, Vol. 50, No. 1 (April 2024), Vol. 50, No. 2, (August 2024), and Vol. 50, No. 3 (December 2024). Both publications are available on the GSM website (https://gsm.org.my/). Remedial work to ensure that every article is correctly linked in the new GSM website requires constant monitoring. We seek the support of members to conduct regular checks and alert the GSM Secretariat of any broken links or errors.

Both the publications have been indexed by Scopus and the Malaysian Citation Index / MyCite. In 2024, the Scopus CiteScore of the Bulletin continued to improve to 2.0 with a rank of #108/159 (compared to 1.6 with a rank of #102/141 in the previous year). The Scopus CiteScore of Warta Geologi is 0.1 with an entry rank of #317/321. An application has been made for both the scientific journals of GSM to be indexed by the Web of Science after resolving technical issues related to the e- ISSN status of the journals. From now on, the GSM website will have to be stringently monitored for easy access. An application will be made for the registration of Warta Geologi to the Directory of Open Access Journals (DOAJ) by end-2025. The Bulletin is already registered with the DOAJ. The online manuscript submission via the Open Journal System (OJS), which has been suspended during transfer to the new GSM website will also commence this year.

In 2024, GSM in collaboration with PETRONAS, published the "Pollen and Spore Atlas for the Cenozoic of the Malay Basin, Malaysia" by Robert J. Morley and Jaizan Hardi Mohamed Jais. The Atlas is available on the website and serves as a valuable resource for stratigraphic palynologists working on the Oligocene to Pliocene succession of the Malay Basin. The GSM would like to acknowledge PETRONAS for their support in this publication.

The GSM is also grateful to all the authors for their contributions, reviewers for their time and effort to improve the quality of the scientific papers, and members of the Editorial Board for their support. The list of all reviewers for Bulletin and Warta Geologi in 2024 will be listed in the upcoming issue of Warta Geologi. Upon request, reviewers are also provided with a certificate regardless of whether the manuscripts they reviewed were eventually accepted or declined.

I would like to acknowledge the Editorial Board, Assistant Editors, Editorial Manager, Production Editorial Managers, GSM Council Members and Trustees of the GSM Endowment Fund for their unwavering support in the past year. I especially record my appreciation to Dr. Iskandar Taib, Ms. Wan Aida Wan Zahari, Ms. Nazatul Athirah Abdul Khalil, Ms. Anna Lee and Dr. Ng Tham Fatt. Finally, I express my deepest gratitude to all the authors, contributors and reviewers of both the Bulletin and Warta Geologi in 2024.

JOY JACQUELINE PEREIRA
Editor
Geological Society of Malaysia

Treasurer's Report

For the Financial Year 2024, the Society posted an increased surplus of income over expenditure, rising from RM 90,087 in 2023 to RM 110,064.

Total sundry income (excluding time deposit interest) increased from RM 157,425 in 2023 to RM 178,450. Total operating expenses decreased slightly to RM 130,721, compared to RM 131,128 in 2023.

The income was derived from several main sources: (i) Sales of publications in the form of royalties from AAPG; (ii) The National Geoscience Conference in 2024; and (iii) Membership fees. Sales of publications in the form of royalties increased from RM 67,093 in 2023 to RM 83,693. Membership subscriptions also saw a significant rise, from RM 14,318 in 2023 to RM 23,455.

The major expenses were salaries and honorariums. The printing cost for Warta Geologi and the Bulletin increased slightly from RM 14,775 in 2023 to RM 20,350; however, this is still significantly lower than the amount of over RM 40,000 incurred when the Society was publishing full hard copies prior to the year 2000.

In 2024, the Society awarded a total of RM 8,000 for student awards via their respective geology departments in universities. In 2023, only a total of RM 5,000 was awarded. A disbursement of RM 1,000 was made for student activities organized mainly under university geology clubs, which was lower than the RM 1,506 disbursed in 2023.

There was a slight decrease in interest rates on fixed deposits, from RM 67,093 in 2023 to RM 63,022, which includes approximately 78% of the interest earned in the Endowment Fund account.

The Treasurer wishes to express deep appreciation to donors, sponsors, and all contributors for their support throughout the year. Special thanks are extended to the GSM Endowment Fund and the shared resources from projects jointly carried out with SEADPRI-UKM, which funded allowances for human resources and electronic journal publishing, including the websites for publication and submission. Lastly, heartfelt gratitude is extended to Ms. Anna Lee for her invaluable contribution in managing the accounts and addressing numerous miscellaneous tasks throughout the year.

LIM CHOUN SIAN
Treasurer
Geological Society of Malaysia

PERSATUAN GEOLOGI MALAYSIA
(GEOLOGICAL SOCIETY OF MALAYSIA)
(Society no : PPM-001-14-10011967)
(Registered under the Societies Act, 1966)

FINANCIAL STATEMENTS
31 DECEMBER 2024

PERSATUAN GEOLOGI MALAYSIA
(GEOLOGICAL SOCIETY OF MALAYSIA)
(Society No: PPM-001-14-10011967)
(Registered under the Societies Act, 1966)

<u>THE SOCIETY INFORMATION FOR 2024 / 2025</u>

President	:	Mohd Hariri Arifin
Vice President	:	Meor Hakif Amir Hassan
Immediate Past President	:	Ahmad Nizam Hasan
Secretary	:	Ling Nan Ley
Assistant Secretary	:	Norazianti Asmari
Treasurer	:	Lim Choun Sian
Editor	:	Joy Jacqueline Pereira
Councillors	:	Allagu Balaguru
	:	Muhammad Ashahadi Dzulkafli
	:	Cindy Simba Ngumbang Ak Kadir
	:	Mohd Shafiq Firdauz Abdul Razak
	:	Muhammad Hatta Roselee
	:	Muhammad Azri Ismail
	:	Siti Nur Fathiyah Jamaludin
	:	Tan Boon Kong
Auditors	:	S.F. Lee & Co. (AF : 0670) No.5-3, Udarama Complex, Jalan 1/64A, Off Jalan Ipoh, 50350 Kuala Lumpur. Tel: 03-40410540 Fax: 03-40410586
Registered Office	:	c/o Department of Geology, University of Malaya, 50603 Kuala Lumpur.
Bankers	:	United Overseas Bank (Malaysia) Berhad
	:	Standard Chartered Bank

PERSATUAN GEOLOGI MALAYSIA
(GEOLOGICAL SOCIETY OF MALAYSIA)
(Society No: PPM-001-14-10011967)
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FINANCIAL STATEMENTS 31 DECEMBER 2024

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PERSATUAN GEOLOGI MALAYSIA
(GEOLOGICAL SOCIETY OF MALAYSIA)
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STATEMENT BY THE COUNCIL

We, Mohd Harifi Arifin and Lim Choun Sian, being the President and Treasurer of the Council of Persatuan Geologi Malaysia (Geological Society Of Malaysia), do hereby state that, in our opinion, the accompanying financial statements set out pages 5 to 16 are drawn up in accordance with Malaysian Private Entities Reporting Standard and the requirements of the Societies Act, 1966 in Malaysia so as to give a true and fair view of the financial position of the Persatuan Geologi Malaysia (Geological Society Of Malaysia), as at 31 December 2024, and of the financial performance and cash flows of the Society for the year then ended.

Signed on behalf of the Council

Mohd Harifi Arifin
President

Lim Choun Sian
Treasurer

Dated: 20 MAR 2025

Kuala Lumpur

STATUTORY DECLARATION

I, Lim Choun Sian, being the Treasurer primarily responsible for the financial management of Persatuan Geologi Malaysia (Geological Society Of Malaysia), do solemnly and sincerely declare that the accompanying financial statements set out on pages 5 to 16 are in my opinion correct, and I make this solemn declaration conscientiously believing the same to be by virtue of the provisions of the Statutory Declarations Act, 1960.

Subscribed and solemnly declared by abovenamed
Lim Choun Sian at Kuala Lumpur in Wilayah
Persekutuan on 20 MAR 2025

Lim Choun Sian

Before me,

Kuala Lumpur

PESURUHJAYA SUMPAH
W728
HJ. WAN AZMAN B. HJ. WAN ABDULLAH
1 JAN 2024 - 31 DEC 2026
MALAYSIA

1

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Batu 2½, 51200 Kuala Lumpur
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Email: wan.azman09@gmail.com

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

No. 5-3, Jalan 1/64A,
Kompleks Udarama, Off Jalan Ipoh,
50350 Kuala Lumpur.
Tel : 03 - 4042 7546
Fax : 03 - 4041 3749
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INDEPENDENT AUDITORS' REPORT
TO THE MEMBERS OF PERSATUAN GEOLOGI MALAYSIA (GEOLOGICAL SOCIETY OF MALAYSIA)

Report on the Financial Statements

Opinion

We have audited the financial statements of **Persatuan Geologi Malaysia (Geological Society Of Malaysia),** which comprise the statement of financial position of the Society as at 31 December 2024, the statement of comprehensive income and statement of cash flows of the Society for the year then ended, and a summary of significant accounting policies and other explanatory notes, as set out on pages 5 to 16.

In our opinion, the accompanying financial statements give a true and fair view of the financial position of the Society as at 31 December 2024, and of its financial performance and its cash flows for the year then ended in accordance with Malaysian Private Entities Reporting Standard and the requirements of the Societies Act, 1966 in Malaysia.

Basis for opinion

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

Independence and Other Ethical Responsibilities

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

Responsibilities of the Council for the Financial Statements

The council of the Society are responsible for the preparation of financial statements of the Society that give a true and fair view in accordance with Malaysian Private Entities Reporting Standard and the requirement of the Societies Act, 1966 in Malaysia. The council are also responsible for such internal control as council determine is necessary to enable the preparation of financial statements of the Society that are free from material misstatements, whether due to fraud or error.

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

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

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

PERSATUAN GEOLOGI MALAYSIA
(GEOLOGICAL SOCIETY OF MALAYSIA)
(Society No: PPM-001-14-10011967)
(Registered under the Societies Act, 1966)

Auditor's Responsibilities for the Audit of the Financial Statements

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

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

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

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

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

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

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

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

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

Report on Other Legal and Regulatory Requirements

In accordance with the requirements of the Societies Act, 1966 in Malaysia, we also report that in our opinion the accounting and other records and the registers required by the Act to be kept by the Society have been properly kept in accordance with the provisions of the Act.

Other Matter

This report is made solely to the members of the Society, as a body, in accordance with the Societies Act, 1966 in Malaysia, and for no other purpose. We do not assume responsibility to any other person for the content of this report.

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

LEE SIEW FATT
01179/09/2026 (J)
CHARTERED ACCOUNTANT

Kuala Lumpur
Dated: 20 MAR 2025

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PERSATUAN GEOLOGI MALAYSIA
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STATEMENT OF FINANCIAL POSITION
As at 31 December 2024

	Note	2024 RM	2023 RM
FUND ACCOUNTS			
GENERAL FUND	4	998,132	896,174
ENDOWMENT FUND	5	2,043,811	2,035,705
STUDENT LOAN FUND		2,055	2,055
YOUNG GEOSCIENTIST AWARD FUND		3,143	3,143
		3,047,141	2,937,077
Represented by:			
NON-CURRENT ASSETS			
PROPERTY, PLANT AND EQUIPMENT	6	7,914	9,277
CURRENT ASSETS			
Time deposits with licensed bank	7	2,479,701	2,479,701
Cash and bank balances		751,208	528,528
		3,230,909	3,008,229
CURRENT LIABILITIES			
Other payables and accrued expenses	8	191,147	78,379
Current tax liabilities		535	2,050
		191,682	80,429
NET CURRENT ASSETS		3,039,227	2,927,800
		3,047,141	2,937,077

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

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PERSATUAN GEOLOGI MALAYSIA
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STATEMENT OF COMPREHENSIVE INCOME
For the year ended 31 December 2024

	Note	2024	2023
		RM	RM
INCOME			
Sundry income	9	178,450	157,425
Time deposits interest		63,022	67,180
		241,472	224,605
EXPENDITURE			
Administrative and operating expenses	10	(130,721)	(131,128)
Surplus before taxation		110,751	93,477
Tax expense	11	(687)	(3,390)
Surplus for the financial year		110,064	90,087
Represented By:			
General fund		101,958	36,884
Endowment fund		8,106	53,203
		110,064	90,087

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

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PERSATUAN GEOLOGI MALAYSIA
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STATEMENT OF CHANGES IN FUNDS
For the year ended 31 December 2024

	Endowment Fund RM	General Fund RM	Total RM
At 1 January 2023	1,982,502	859,290	2,841,792
Surplus of income over expenditure for the year	53,203	36,884	90,087
At 31 December 2023	2,035,705	896,174	2,931,879
Surplus of income over expenditure for the year	8,106	101,958	110,064
At 31 December 2024	2,043,811	998,132	3,041,943

The accompanying notes are an integral part of the financial statements

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PERSATUAN GEOLOGI MALAYSIA
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STATEMENT OF CASH FLOWS
For the year ended 31 December 2024

	2024 RM	2023 RM
Cash flows from operating activities		
Surplus of income over expenditure for the year	110,751	93,477
Adjustments for:-		
Interest income	(23,022)	(67,180)
Depreciation on property, plant & equipment	1,363	1,633
Surplus before working capital changes	89,092	27,930
Increase / (decrease) in other payables	112,766	(163,410)
Cash generated from / (used in) operations	201,858	(135,480)
Tax paid	(1,613)	(2,869)
Net cash used in operating activities	200,245	(138,349)
Cash flows from investing activities		
Interest income	23,022	67,180
Increase of student loan fund	-	300
Purchase of property, plant and equipment	-	(2,299)
Net cash used in investing activities	23,022	65,181
Cash flows from financing activities		
Advance from third parties	(589)	-
Net cash used in operating activities	(589)	-
Net increase / (decrease) in cash and cash equivalents	222,680	(73,168)
Cash and cash equivalents at beginning of the year	3,008,229	3,081,397
Cash and cash equivalents at end of the year	3,230,909	3,008,229

<u>**Cash and cash equivalents comprised of:**</u>	2024 RM	2023 RM
Deposits with licensed banks	2,479,701	2,479,701
Cash at bank	750,928	527,793
Cash in hand	280	735
	3,230,909	3,008,229

The accompanying notes are an integral part of the financial statements

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PERSATUAN GEOLOGI MALAYSIA
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NOTES TO THE FINANCIAL STATEMENTS –31 DECEMBER 2024

1. GENERAL INFORMATION

The principal activity of the Society is to promote the advancement of the geological sciences in Malaysia. The Persatuan Geologi Malaysia (Geological Society Of Malaysia) is a registered Society under Societies Act, 1966.

The registered office of the Society is located at c/o Department of Geologi, University of Malaya, 50603 Kuala Lumpur.

The financial statements were authorised for issue in accordance with a resolution by the council on 20 MAR 2025

2. BASIS OF PREPARATION

(a) Statement of compliance

The financial statements of the Society have been prepared in accordance with Malaysian Private Entities Reporting Standard ("MPERS") and the requirements of Societies Act. 1966 in Malaysia.

(b) Basis of measurement

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

(c) Functional and presentation currency

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

(d) Use of estimates and judgements

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

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

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3. SUMMARY OF ACCOUNTING POLICIES

(a) Plant and equipment and depreciation

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

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

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

Office equipment	10% - 20%

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

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

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

(b) Impairment of non-financial assets

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

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

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

An impairment loss is recognised if the carrying amount of an asset or its related cash-generating unit exceeds its estimated recoverable amount. Impairment losses are recognised in the income statement. Impairment losses recognised in respect of cash-generating units are allocated to reduce the carrying amounts of cash generating unit on a pro rata basis.

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

(c) Financial instruments

(i) Initial recognition and measurement

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

A financial instrument is recognised initially at the transaction price (including transaction costs except in the initial measurement of a financial asset or financial liability that is measured at fair value through statement of comprehensive income) unless the arrangement constitutes, in effect, a financing transaction. If the arrangement constitutes a financing transaction, the financial asset or financial liability is measured at the present value of the future payments discounted at a market rate of interest for a similar debt instrument.

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(ii) Subsequent measurement

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

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

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

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

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

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

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

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

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

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(iii) Derecognition

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

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

(d) <u>Revenue Recognition</u>

(i) Membership subscription is payable annually at the beginning of the financial year and is recognised on receipt basis.

(ii) Interest earned from time deposit placements are recognized on time proportionate basis.

(iii) Sale of publications is recognised upon delivery of goods sold.

(iv) Seminar income is recognised upon the conduct of the respective seminars.

(e) Taxation

Current tax expense is determined according to the Malaysia tax laws substantially enacted by the reporting date and includes all taxes based upon the taxable profits.

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PERSATUAN GEOLOGI MALAYSIA
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4. GENERAL FUND

	2024 RM	2023 RM
At 1 January	896,174	859,290
Surplus for the year	101,958	36,884
At 31 December	998,132	896,174

The General Fund can be utilised at the discretion of the council members.

5. ENDOWMENT FUND

	2024 RM	2023 RM
At 1 January	2,035,705	1,982,502
Surplus for the year	8,106	53,203
At 31 December	2,043,811	2,035,705

The Endowment Fund can only be utilised with the approval of the members at the Annual General Meeting.

6. PLANT AND EQUIPMENT

	Office equipment RM
Cost	
At 1 January 2024	32,849
Additions	-
Disposal and deletion	-
At 31 December 2024	32,849
Accumulated depreciation and impairment losses	
At 1 January 2024	23,572
Charge for the year	1,363
Disposal and deletion	-
At 31 December 2024	24,935
Carrying amounts at 1 January 2024	9,277
Carrying amounts at 1 December 2024	7,914

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7. TIME DEPOSITS WITH LICENSED BANKS

	2024 RM	2023 RM
General fund	537,701	537,701
Endowment fund	1,942,000	1,942,000
	2,479,701	2,479,701

The time deposits with licensed banks have an average maturity of between 3 to 15 months (2023: 3 to 15 months). Interest rates for the deposits ranged from 1.60% to 3.20% (2023: 1.6% to 2%) per annum.

8. OTHER PAYABLES AND ACCRUED EXPENSES

	2024 RM	2023 RM
Other payables	189,302	76,379
Accrued expenses	1,845	2,000
	191,147	78,379

9. SUNDRY INCOME

	2024 RM	2023 RM
Donation received	3,038	-
Entrance fee	1,160	920
Membership fee	23,455	14,318
Publications	85,857	68,836
Geology of Peninsular Malaysia	3,195	6,860
National Geoscience Conference	60,095	45,475
Geological Evolution of Southeast Asia	1,650	1,125
Souvenirs	-	2,850
Geosea	-	17,041
	178,450	157,425

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10. ADMINISTRATIVE AND OPERATING EXPENSES

	2024 RM	2023 RM
Audit fee	2,300	2,000
Best student award	8,000	5,000
Depreciation on property, plant and equipment	1,363	1,633
Department of geology	12,000	24,000
Donation	1,000	1,358
Geosea	-	635
Honorarium	36,060	24,080
Printing and stationary	21,926	16,464
Professional fee	2,200	800
Subscription	1,628	1,416
Website maintenance	-	8,224
Other expenses	44,244	45,518
	130,721	131,128

11. TAX EXPENSE

Income tax is provided for investment income and on surplus arising from transactions with non-members.

	2024 RM	2023 RM
Current tax on result for the year	687	3,390

12. FINANCIAL INSTRUMENTS

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

	2024 RM	2023 RM
Financial assets measured at amortised cost less impairment		
Time deposits with licensed bank	2,479,701	2,479,701
Cash and bank balances	751,208	528,528
	3,230,909	3,008,229
Financial liabilities carried at amortised cost		
Other payables and accrued expenses	191,147	78,379

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STATEMENT OF INCOME AND EXPENDITURE
For the year ended 31 December 2024

INCOME	2024 RM	2023 RM
Entrance fee	1,160	920
Time deposits interest income	63,022	67,180
Membership fee	23,455	14,318
Geology of Peninsular Malaysia	3,195	6,860
National Geoscience Conference	60,095	45,475
Publications : Sales	1,664	1,743
Publications : Topi Bulat	500	-
Publications : AAPG royalties	83,693	67,093
Geological Evolution of Southeast Asia	1,650	1,125
Souvenirs	-	2,850
Geosea	-	17,041
Donation received	3,038	-
	241,472	224,605
EXPENDITURE		
Annual dinner	4,174	3,401
Audit fee	2,300	2,000
Staff EPF and Socso	7,816	6,064
Bank charges	81	188
Best Student's award (UKM and UM)	8,000	5,000
Board of geologist fee	700	1,300
Depreciation on property, plant and equipment	1,363	1,633
Department of Geology	12,000	24,000
Donation	1,000	1,358
Event attendance	-	1,601
Geosea	-	635
Geology of peninsular Malaysia	-	3,727
Geological Evaluation of southeast Asia	-	275
Honorarium	36,060	24,080
Miscellaneous expenses	1,856	3,629
Postages	488	845
Printing and Stationery		
- Warta Geologi	12,500	6,650
- Bulletin	7,850	8,125
- Stationery	1,576	1,689
Professional fee	2,200	800
Refreshment	709	504
Service tax	120	120
Souvenirs	104	-
Subscription fee	1,628	1,416
Salary	25,915	20,536
Studend events	1,000	1,506
Speakers expenses	144	402
Telephone and fax	1,137	1,420
Website maintenance	-	8,224
	130,721	131,128
Surplus before tax	110,751	93,477

GSM Endowment Fund Report

GSM ENDOWMENT FUND: BOARD OF TRUSTEES REPORT FOR THE 59th ANNUAL GENERAL MEETING OF THE GEOLOGICAL SOCIETY OF MALAYSIA
25 April 2025

Background

1. The 47th AGM in 2013 confirmed the establishment of the GSM Endowment Fund and endorsed the Terms of Reference prepared by Advocates and Solicitors, Messrs Yeap, Yong and Amy.

2. The 48th AGM in 2014 approved an amendment to the Terms of Reference to provide for the establishment of the "Board of Trustees of the GSM Endowment Fund", whose members shall comprise the GSM President, Immediate Past President, Secretary, Treasurer, Editor and at least three independent Full Members "in good standing", to be appointed at the AGM in 2017, 2020, 2023, 2026, 2029, 2032 etc.

3. The 53rd AGM in 2019 was informed that the GSM Council undertook a search on the website of "Lembaga Hasil Dalam Negeri" (LHDN) and found that GSM is listed as an organisation that is approved to collect donations under Subsection 44(6) since the year 1967. The GSM has "tax deductible" status that allows individuals and organizations to obtain tax exemption for their donations. The LHDN has informed GSM that the "tax deductible" status will expire in December 2025.

4. The 55th AGM in 2021 was informed that the GSM Council has developed a procedure for issuance of receipts for tax exemption and to inform LHDN for donations of RM 5,000 and above.

5. The 57th AGM in 2023 also appointed YBhg. Dato' Yunus Abd Razak as Chair of the Board of Trustees of the GSM Endowment Fund, with Dr. Lee Chai Peng, Dr. Wan Hasiah Abdullah and Puan Azimah Ali as independent Full Members to serve until the AGM in 2026.

6. Items pending from the 58th AGM held on 23 April 2024 are as follows:

   (i) The GSM Council is requested to report progress to the Board of Trustees of the GSM Endowment Fund regarding implementation of the proposed modality for using accumulated interest earned (RM 14,946.16 as of 31 December 2023) from the donation of RM 50,000.00 by YBhg. Dato' Sia Hok Kiang to the GSM Endowment Fund in 2014.

Report of the Board of Trustees

1. This report covers the period from 1 January 2024 to 31 December 2024. The Board of Trustees met on 17 April 2025 (Thursday) on a hybrid mode, physically at SEADPRI-UKM and on Zoom, to scrutinise the administration of the GSM Endowment Fund. The meeting was moderated by the Chair, YBhg. Dato' Yunus Abd Razak. Members in attendance were Dr. Lee Chai Peng (online), Dr. Wan Hasiah Abdullah (online) and Puan Azimah Ali (online); GSM President, Dr. Mohd Hariri Arifin; Immediate Past President, Mr. Ahmad Nizam Hasan (online); Secretary, Mr. Ling Nan Ley; Treasurer, Dr. Lim Choun Sian; Editor, Prof. Joy Jacqueline Pereira (online). Observer included Puan Nazatul Athirah Abdul Khalil (GSM Secretariat).

2. The principal amount, in the form of fixed deposits with the United Overseas Bank Malaysia (UOB) as reflected in the bank statement is currently RM 1,941,999.99.

3. A special Current Account is also maintained with UOB to receive the interest accrued from the principal amount. The interest is kept in this GSM Current Account at UOB (which is separate from the operational

account of GSM at the Standard Chartered Bank Bhd.). The annual interest accrued from the fixed deposits in 2024 is RM 61,336.44. The balance in the Current Account of the Endowment Fund as of 31 December 2024 is RM 61,780.64. The balance in the Current Account of the Endowment Fund in the previous year (as of 31 December 2023) was RM 53,674.70.

4. On 19 November 2024, the GSM Council transferred RM 53,200.00 from a UOB Current Account to the operational account of GSM at Standard Chartered Bank Bhd. This transfer was approved by the AGM in 2024 for publication purposes and to subsidise students attending the GSM Annual Geoscience Conference. A cheque processing fee of RM 0.50 was charged.

5. The accumulated interest earned from the donation of RM 50,000.00 by YBhg. Dato' Sia Hok Kiang to the GSM Endowment Fund in 2014 for research on economic geology is RM 16,483.70 as of 31 December 2024. The GSM Council has prepared the promotion poster and application form for research proposals on economic geology from graduate and postgraduate students. More details will be provided on the GSM website.

6. Recommendations of the Board of Trustees to the 59th AGM of the GSM on 25 April 2025 are as follows:
   (i) The GSM Council is requested to apply for an extension of its "tax deductible" status from the LHDN as soon as possible before December 2025.
   (ii) The AGM is requested to approve the sum of RM 40,000.00 that is requested by the GSM Council for the publications for the year 2025. The GSM Council is requested to report the usage of the fund to the Board of Trustees of the GSM Endowment Fund.
   (iii) The GSM Council is requested to increase the principal amount in the GSM Endowment Fund by RM 50,000.00.
   (iv) The AGM is requested to consider the inclusion of the GSM Vice President at every meeting of the GSM Endowment Committee.

On behalf of the Board of Trustees, I declare that I am satisfied that the GSM Endowment Fund is being administered in a satisfactory manner and that the terms of reference are adhered to. I hereby approve the report prepared for the 59th AGM of the GSM.

Dato' Yunus Abd Razak
Chairman
Board of Trustees of the GSM Endowment Fund
Geological Society of Malaysia
17 April 2025

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

Geological Society of Malaysia Election Terms for 2025/2026

The following nominations were received by the Council by 4th October 2024:

Position (No. of Seat)	No. of Nomination	Nomination
President (1)	1	Meor Hakif Amir Hassan
Vice President (1)	1	Tanot Unjah
Secretary (1)	1	Ling Nan Ley
Assistant Secretary (1)	1	Norazianti Asmari
Treasurer (1)	1	Lim Choun Sian
Editor (1)	1	Joy Jacqueline Pereira
Councillors (4) - to serve two-year term 2025-2027	4	(1) Arindam Chakraborty (2) Hamzah Bin Hussin (3) Mohamad Shaufi Sokiman (4) Suraya Hilmi Hazim

Voting is not required for the Geological Society of Malaysia's 2025/2026 election terms, as each position received only one nomination.
In addition, there are four current Councillors who will be serving the second year of their two-year term (2024-2025/2025-2026):

1. Allagu Balaguru
2. Muhammad Ashahadi Dzulkafli
3. Muhammad Azri Ismail
4. Tan Boon Kong

Sincerely,

Shafiq

Mohd Shafiq Firdauz
Nomination Committee
27 December 2024

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REPORT TITLE: **GSM COUNCIL ELECTION TERM 2025/2026 RESULT**

REPORT DATE: **29 DECEMBER 2024**

This document contains the result of the Geological Society of Malaysia (GSM) Council Election for the term 2025/2026. At the end of the nomination period on 30 September 2024, nominations were received for all Council positions. Only a single nomination was received for all positions.

With the above results, the Council office for the term 2025/2026 shall be filled as follows:

President: Meor Hakif Bin Amir Hassan
Vice-President: Tanot Unjah
Immediate Past President: Mohd Hariri Arifin
Secretary: Ling Nan Ley
Treasurer: Lim Choun Sian
Assistant Secretary: Norazianti Asmari
Editor: Joy Jacqueline Pereira

Councillors for Term 2024/2025-2025/2026 (serving the second year of their two-year term)

- Allagu Balaguru
- Muhammad Ashahadi Dzulkafli
- Muhammad Azri Ismail
- Tan Boon Kong

Councillors for Term 2025/2026 – 2026/2027 (two-year term)

- Arindam Chakraborty
- Hamzah Bin Hussin
- Mohamad Shaufi Sokiman
- Suraya Hilmi Hazim

End of report.

Report prepared by Election Officer dated 29 December 2024.

Shafiq

Mohd Shafiq Firdauz
Nomination Committee
27 December 2024

CERAMAH TEKNIK TECHNICAL TALK

Geological evaluation study of Batu Arang, Gombak from geoheritage to geohazard

P. Geol. Ahmad Nizam Hasan
Geosolution Resources
Date: 23 April 2025
Platform: Zoom

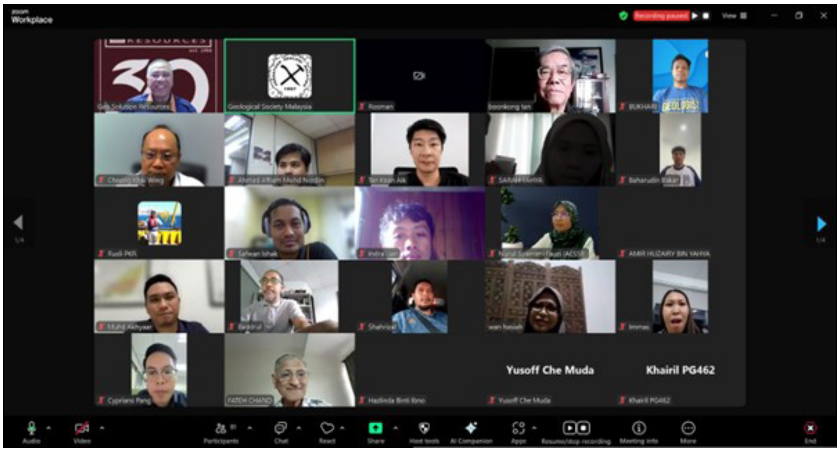
The above talk was delivered by P. Geol. Ahmad Nizam Hasan on 23rd April, 2025 via Zoom. Some 137 members participated. An abstract of the talk is given below:

Abstract: The study was carried out under the department of Plan Malaysia@Selangor for the purpose of identifying potential geohazard in the development planning of Batu Arang geoheritage township. The comprehensive geological study that comprises detail surface and subsurface investigation indirectly producing the highly useful informative data in strengthening present geoheritage archives.

Batu Arang town in Selangor has a rich history of coal mining, which began in 1915 and lasted until 1960. This study assesses the geological and geotechnical hazards in the area, particularly the risks of land subsidence and sinkholes due to past underground (UG) and open-cast mining (OC) activities. The study focuses on three key mining clusters based on their association with orthodox underground mining activities: Old North Mine, Old South Mine, and Old Centre Mine & No. 2 Mine. Geologically, the area comprises three main formations: Kenny Hills Formation (Permian), Batu Arang Beds (Late Oligocene to Miocene), and Boulder Beds (Quaternary). While there are 2 main Coal Seam being mines which is Upper Coal Seam with an average thickness of 15m dan Lower Coal Seam with an average thickness of 8m and an average dip angle of 14° westerly direction.

The study involved surface and subsurface geological mapping, including geophysical surveys and borehole drilling, to analyze soil and rock conditions. Findings indicate that subsidence and sinkholes mainly occurred in areas with historical underground mining that lacked proper rehabilitation. A hazard zoning map was developed using GIS technology, combining heuristic and empirical methods such as the Analytic Hierarchy Process (AHP). The heuristic approach identified factors contributing to geological hazards, such as mining activities, void structures, historical geological hazard data, coal seam layering, and geological conditions. The empirical approach used the Analytic Hierarchy Process (AHP) with pairwise comparisons and weightage scores (0.5 = equally important, 1 = important, 2 = very important). A Raster Calculator geospatial analysis was applied to create thematic maps of potential geological hazard zones, revealing that 73.29% of the study area falls into the Low Hazard Zone, 23.15% into the Moderate Hazard Zone, and 4.56% into the High Hazard Zone. Further subsurface analysis identified risk zones based on coal seam depth. These findings provide essential insights for land use planning and disaster risk management in Batu Arang.

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



Prepared by,
Tan Boon Kong
Chairman, Working Group on Engineering Geology & Environmental Geology

CERAMAH TEKNIK TECHNICAL TALK

Common challenges in cavity detection

P. Geol. Devendran Arumugam
Gamuda Berhad
Date: 21 May 2025
Platform: Zoom

The above talk was delivered by P. Geol. Devendran Arumugam on 21st May, 2025 via Zoom. Some 100 members participated. An abstract of the talk is given below:

Abstract: Karst formation is the result of dissolution of carbonate rocks such as limestone and dolomite. Limestone found in Malaysia is largely extreme karst V, whereby much of the carbonate rocks have undergone dissolution and weathering.

Dissolution of the limestone results in many features such as large and small caves, pinnacles, troughs, solution channels, steep sided rock, undercuts, dolines, jiggered bedrock, sinkholes and depressions.

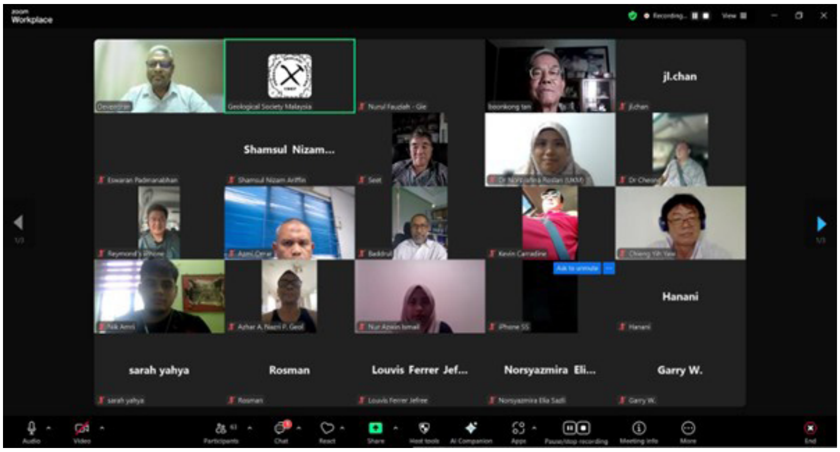
There are many engineering projects that call for identification of these features to design foundations, earth retaining systems, deep excavations, tunneling projects and pile detection. The solution channels and cavities when exposed during construction can become sinks for groundwater flow and thus possibly cause depressions and sinkholes.

Kuala Lumpur geology is complex underlain by granite, Kenny Hill Formation, limestone (marble) and quartz. The complex geology and its associated geological features make cavity detection a challenge.

Often geophysics is the major method of cavity detection. The techniques used include seismic refraction, MASW, gravity method, GPR, seismic cross hole tomography and electrical resistivity. Coupled with borehole investigation, rock probing and drone mapping cavity detection can have a high success rate.

In this presentation examples from SMART tunnel, MRT KJ and PJ lines will be discussed to illustrate the challenges and the lessons learnt.

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



Prepared by,
Tan Boon Kong
Chairman, Working Group on Engineering Geology & Environmental Geology

CERAMAH TEKNIK TECHNICAL TALK

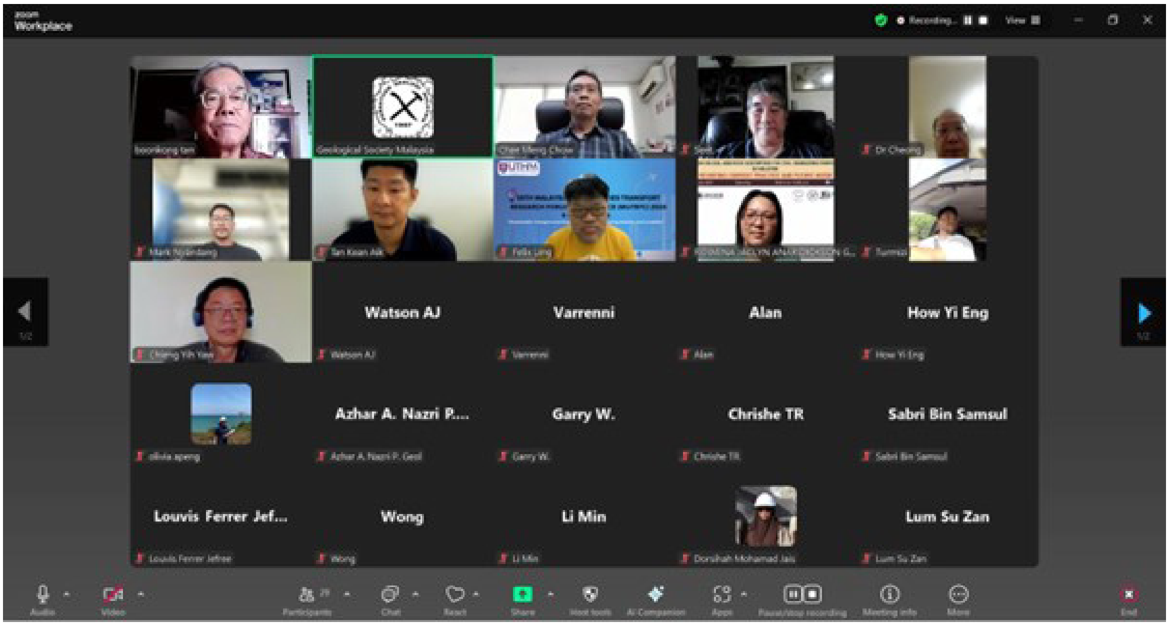
Common challenges in design and construction of injection piles on limestone

Ir. Chow Chee Meng
G&P Geotechnics Sdn Bhd
Date: 18 June 2025
Platform: Zoom

The above talk was delivered by Ir. Chow Chee Meng on 18th June, 2025 via Zoom. Some 56 members participated. An abstract of the talk is given below:

Abstract: Large diameter injection piles (or more commonly known as jack-in pile in Malaysia) has been successfully adopted in Malaysia since late 1990s and currently, large diameter spun piles of up to 600mm in diameter with working load as high as 3200kN have been successfully adopted for high-rise buildings up to 45-storeys. This presentation summarises some experiences and challenges in design and construction of high capacity jack-in pile systems in limestone formation especially for ground with shallow limestone bedrock. Some comparison will also be made between the performance of the piles in granite formation and limestone formation in order to illustrate the challenges associated with injection piles on limestone.

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

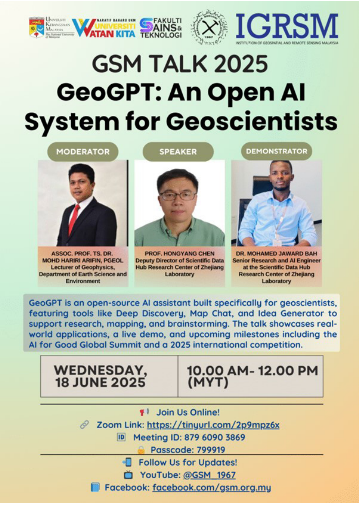


Prepared by,
Tan Boon Kong
Chairman, Working Group on Engineering Geology & Environmental Geology

CERAMAH TEKNIK TECHNICAL TALK

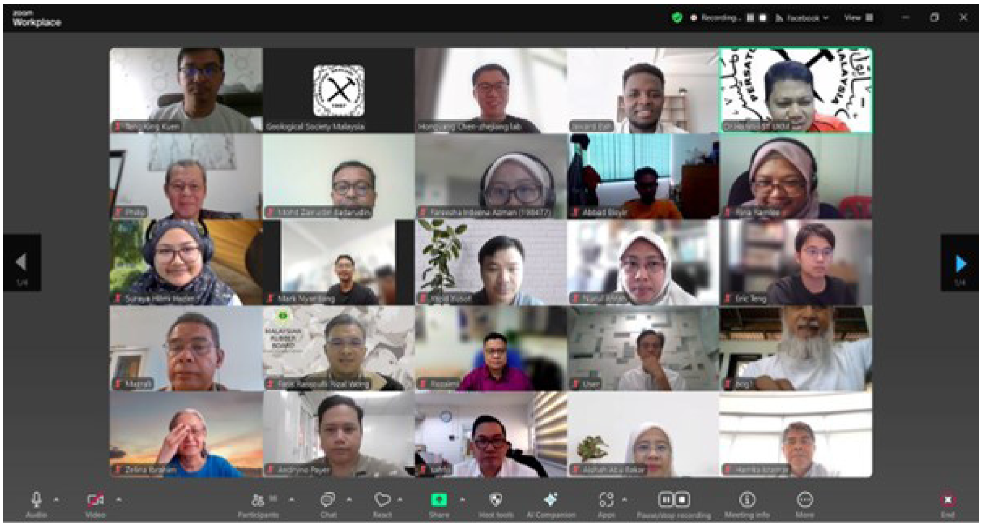
GeoGPT: An open AI system for geoscientists

1) Prof. Hongyang Chen (Speaker)
Deputy Director, Scientific Data Hub Research Center of Zhejiang Laboratory
2) Dr. Mohamed Jaward Bah (Demonstrator)
Senior Research and AI Engineer, Scientific Data Hub Research Center of Zhejiang Laboratory
Date: 18 June 2025
Platform: Zoom



This talk introduces GeoGPT, an open-source AI system designed specifically for geoscientists, acting as a specialist assistant rather than a generalist LLM. We will explore its **innovative architecture**, including tools like *Deep Discovery* (research automation), *Map Chat* (interactive mapping), and *Idea Generator* (AI-driven brainstorming). Case studies - such as paleontological fossil databases, magmatic rock analysis, and petroleum geology knowledge graphs -will demonstrate GeoGPT's real-world impact. Attendees will also see a live demo of its capabilities and learn about its role in promoting **global open** science collaboration. Finally, we'll discuss upcoming milestones, including the *AI for Good Global Summit* and an international competition in Fall 2025.

Some key important about this topic/talk:
1) GeoGPT was developed by researchers including Yifan Zhang and others, and published in July 2023, with a peer-reviewed article in the International Journal of Applied Earth Observation and Geoinformation in mid-2024 (https://www.sciencedirect.com/science/article/pii/S1569843224003303?utm_source=chatgpt.com)
2) GeoGPT was developed by the Deep-time Digital Earth (DDE) initiative, funded largely by Chinese institutions, and endorsed by the International Union of Geological Sciences (IUGS).
3) Unlike generic ChatGPT or simple geocoding packages (such as the Python package that automates geocoding with an LLM fallback), GeoGPT is reserved for full geospatial workflows.
4) Further communication can contact speakers at hongyang@zhejianglab.org or easybah@zhejianglab.org



Prepared by,
Assoc. Prof. Ts. Dr. Mohd Hariri Arifin; P.Geol
Immediate Past President for Geological Society of Malaysia

CERAMAH TEKNIK TECHNICAL TALK

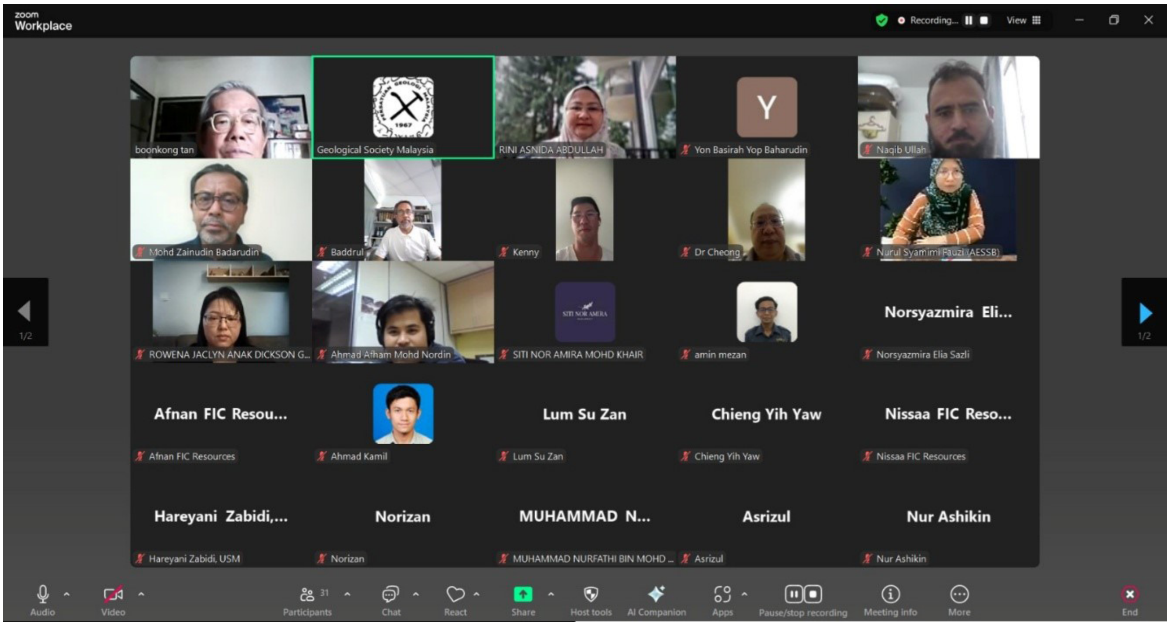
Initial insights into block-in-matrix slopes: Challenges and characterisation in tropical terrain

Ir. Assoc. Prof. Dr. Rini Asnida Abdullah
Universiti Teknologi Malaysia (UTM)
Date: 23 July 2025
Platform: Zoom

The above talk was delivered by Ir. Assoc. Prof. Dr. Rini Asnida Abdullah (UTM) on 23rd July, 2025 via Zoom. Some 50 members participated. An abstract of the talk is given below:

Abstract: This talk presents the initial findings from an ongoing study on the classification, characterization, and stability assessment of block-in-matrix rocks (Bimrocks) at Taman Bandar Baru Kangkar Pulai (BBKP), Johor. Bimrocks, composed of hard rock blocks within a weaker, weathered matrix, are geotechnically complex due to their heterogeneous structure and unpredictable behavior. Through visual field observations and drone-based photogrammetry, the geometry of blocks and their volumetric block proportion (VBP) were documented—revealing predominantly subangular blocks ranging from 700 mm to 6000 mm and a low VBP of 5.42%. In-situ testing, including Field Vane Shear, Mackintosh Probe, Pocket Penetrometer, and Schmidt Hammer, was conducted to assess the strength of both matrix and block components. Complementary numerical modeling using RS2 (Finite Element Method) demonstrated that increasing block content beyond 30% led to higher total stress and displacement, indicating a decrease in slope stability. As an initial stage of a broader investigation, this work underscores the importance of integrating geological, geotechnical, and digital tools for understanding the behavior of Bim slopes. The outcomes are expected to contribute toward better-informed slope design, risk assessment, and infrastructure development in tropical terrains dominated by Bimrocks.

We thank Sdri Rini for her support and contribution to the Society's activities.



Prepared by,
Tan Boon Kong
Chairman, Working Group on Engineering Geology & Environmental Geology

AAPG-GSM Geopressure 2025

Asia Pacific Geoscience Workshop

The AAPG-GSM Geopressure Workshop 2025, held at Asia GeoHub in Kuala Lumpur on June 10–11, focused on critical challenges in petroleum exploration and production, particularly the handling of overpressured formations and the accurate prediction of pore pressures in deep reservoirs. Beicip-Franlab Asia (BFA) was the main sponsor of the event, which brought together geoscience experts to exchange knowledge and experiences in addressing these issues. Key topics and discussions from the workshop included.

78 geoscientists registered for this workshop, representing 9 nationalities, and 22 institutions. There were 14 talks, which included 4 keynote speeches. The talks ranged from the principles of geopressure to practical example and cases, mainly from the region. There were also case examples from Egypt and the Netherlands.

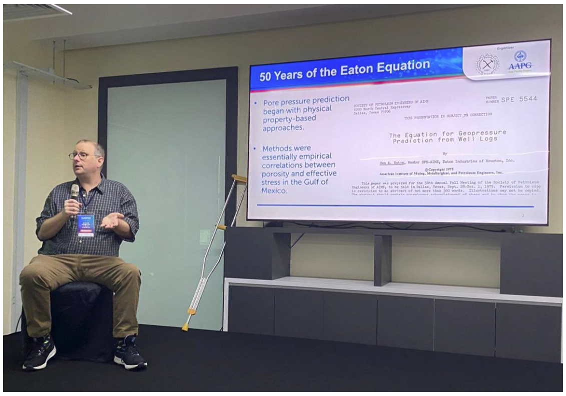
Some highlighted topics are summarized as the following:

- Enhancing pore pressure prediction through geological process-based forward modelling, an advanced method involves understanding elastic and inelastic properties and incorporating post-depositional processes through process-based sedimentation modelling (PSM).
- Pre-Drill Pore Pressure Prediction to minimize uncertainty, multiple methods for pre-drill pore pressure prediction are recommended. Discussions covered the meaning of "offset wells" and procedures for correcting pretest data, including removing hydrocarbon buoyancy effects and calculating overpressured aquifers. It was noted that if a lateral connection exists without pressure, correlated pretest data based on pressure and depth are necessary.

Several studies were presented in the workshop, such as:

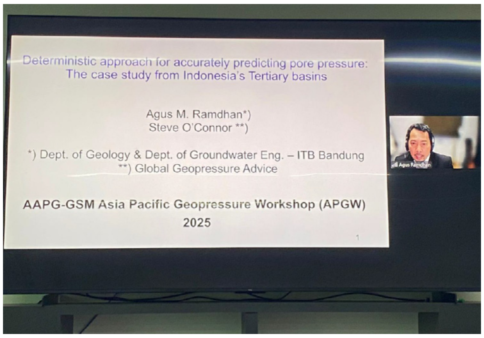
Tempino Field, South Sumatra, Indonesia: discussed the hydraulic fracturing potential to achieve good test / production results.
Kutai Basin, Indonesia: illustrated the loading and unloading mechanisms of overpressure. Density and neutron logs are unique indicators for loading contributions to overpressure.
Tangguh Field, Indonesia: a major gas producer which faces challenges with seismic velocity due to thick carbonate formations, rendering seismic velocity less useful.
Malay Basin, Malaysia: Overpressured zone can cause a decrease in resistivity (Rt) due to water presence.
Netherlands: depleted hydrocarbon fields present an opportunity for carbon dioxide storage.

There were also talks given by the sponsors, Pertamina, Geosoftware and Ikon Geoscience.

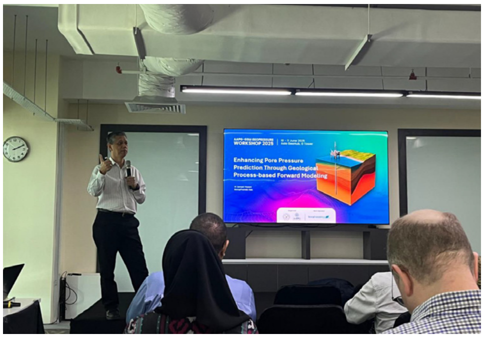


Dr. Mark Tingay from Petronas, delivered his key note speech, titled A Guide To Determining Overpressure Generation Mechanisms and Integration With Pore-Pressure-Prediction Workflow.

Dr. Stephen O'Conor, delivered his key note speech titled A Focus On Pore Pressure Prediction in the Malay Basin.

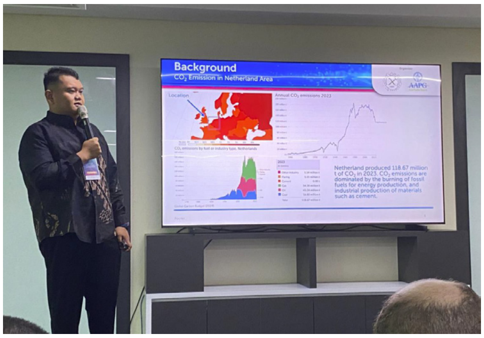


Professor Dr. Agus Ramdhan delivered his talk online from the UK.



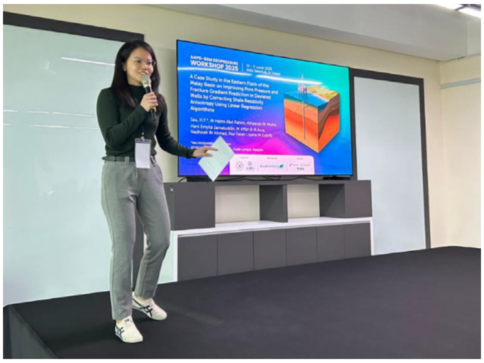
Dr. Jamaal Hoesni, Beicip-Franlab Asia, delivered his talk.

Don Basuki (Pertamina) presented a case study from Tempino Field in South Sumatra, Indonesia.

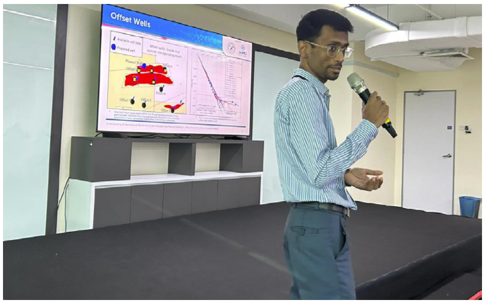


Josua Ricardo Samosir from Indonesia presented a CCS related study in the Netherlands.

Nizam B. M. Zin, from Petronas delivered his talk on pressure and depth corrected pressure data.

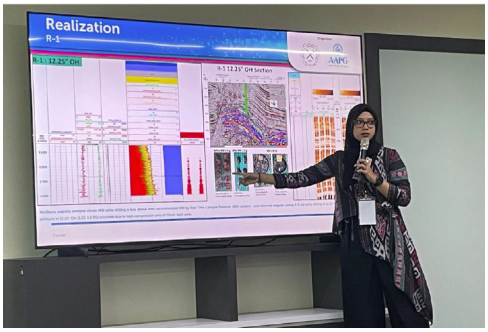


Sau Hooi Yee, from Petronas talked about Improving Pore Pressure and Fracture Gradient Prediction in Deviated Wells.



Avirup Chatterjee (Baker Hughes) talked about Sarawak Offshore case study.

Cokro Suratno (BP) presented a case study from Tangguh Field, Indonesia.



Dhyandra Nugrahandita (Pertamina) gave a talk on Drilling Operation Efficiency through Wellbore Stability Analysis, a case example from Rotan Cinta Field, Indonesia.

Mohamed El Waseef presented his talk on a comprehensive petrophysical and Geomechanical Assessment of Overpressure Impacts on Lower Pliocene-Pleistocene Reservoir Characteristics, Nile Delta, Egypt.

Day 1 presenters together with organizers. From left to right: Josua Ricardo Samosir, Don Basuki, Herman Darman (organizer), Syaza Shamsuddin (organizer), Mark Tingay, and Sau Hooi Yee.

Day 2 presenters together with organizers. From left to right: Syaza Shamsuddin (organizer), Dhyandra Nugrahandita, Herman Darman (organizer), Dr. Jamaal Hoesni, Mohamed El Waseef, and Cokro Suratno.

Participants group photo in day 1.

Participants group photo in day 2.

Prepared by,
Kausalyaa Sarawanan (Universiti Malaya – MSc Student),
Herman Darman (Pertamina)

NEW MEMBERSHIP

Associate Member
1. James Graham Fitton

Confirmation Full Member
1. Hijaz Kamal Hasnan

From Full To Life Member
1. Elanni Md Affandi
2. Jessy Uding Balan

Full Member
1. Allen Marvin Handumon Yutuc
2. Eldawaty Madran
3. Farah Hanani Ismail
4. Ibrahim Danial Maarof
5. Mok Jun Fei
6. Nur Syaza Afina Aiman Nor Azman
7. Nurul Syafida Abu Bakar
8. Ramdhatun Izwah Jasni
9. Sheikh Fadzil Mohamad
10. Syed Bilawal Ali Shah

Student Member
1. Abdul Harith Asmadi
2. Janaarththanan Murali
3. Manauwar Ehsan
4. Mohamad Fiqry Mohd Latif
5. Muhammad Haris Mohd Faisol
6. Muhammad Najmi Anuar Zamani
7. Muhammad Rasyid Redha Mohamad Ridzwan
8. Ng Jie Ling
9. Noor Hidayah Azwa Nor Azalie
10. Nor Ain Amran
11. Nur Farhana Ab Malik Marwan
12. Nurul Husna Rosley
13. Safiah Amirah Mohd Shukri
14. Sharwin Mahendran
15. Siti Nurfatimah Hamidan
16. Siti Nurkhalidah Husainy
17. Siti Nur Aisyah Mamat
18. Sri Nivashini Shanmugaveloo
19. Sufeeya Zulkiflee
20. Syed Rayyan Hashmi
21. Tharani Thamotharan

Current email address of members wanted

The Society would like to have the current email addresses of the following members:

1. Azma Wairah Abdul Aziz
2. Earl Jason Jamanius
3. Fayyadh Aslam Ruhaizin
4. Izzatul Aliah Khairul Anuar
5. Luqmanulhakim Mohd Fauzan
6. Maryam Dahiru Usman
7. Mohd Asraf Hj Khamis
8. Mohd Khairil Faizi Ismail
9. Mohd Muzamil Mohd Hashim
10. Muhammad Aiman Fikri Mohd Sena
11. Muhammad Danish Amri
12. Muhammad Hafiy Ikhwan Khairur Rizal
13. Muhammad Ikhmal Danial
14. Muhammad Zulhadry Hakimi Zukirman
15. Nina Abdul Nuri
16. Nur Aina Maisara Ariff Marlino
17. Nur Alia Amira Azhar
18. Nur Alya Sabrina Mohd Saharom
19. Nur Fathihah Abdullah
20. Nur Fatihah Mohd Yusof
21. Nur Fatin Zulaikha Zuraimi
22. Nurul Aliya Nadira Mohd Hizanuddin
23. Nurul Hidayu Mohammad Daud
24. Rabieahtul Abu Bakar
25. Richlin Martin
26. Seri Almas Mohd Saidin
27. Sirajo Abubakar
28. Siti Aisyah Ahmad Jamil
29. Siti Atiqah Ayub
30. Siti Nur Aimie Fitri Che Ibrahim
31. Siti Nurfatimah Hamidan
32. Wong Yee Huey

ANNOUNCEMENT

GEOLOGICAL SOCIETY OF MALAYSIA

GSM AWARDS 2025

Award Categories:

N.S. HAILE PUBLICATION AWARD

- Any paper on the Earth Sciences relevant to Malaysia or Southeast Asia published in any peer - reviewed journal is eligible for this prize.
- The author (or the first author) must not be more than 30 years in age.
- The paper must have been published within three years prior to the date of the award.
- PRIZE: RM 1000.00 & PLAQUE/CERTIFICATE

HUTCHISON BEST STUDENT AWARD

- Final year students at Geology Departments in Malaysian universities are eligible for this prize.
- PRIZE: RM 1000.00

DJ GOBBETT AWARD "GEOSCIENTIST AWARD"

- GSM Members who have made significant contributions to research in Malaysian Geology are eligible for this award.
- PRIZE: PLAQUE

MORE INFORMATION

CONTACT MS. NORAZIANTI ASMARI
CHAIRPERSON GSM AWARDS 2025

017-6166158

ANNOUNCEMENT

Board Of Geologists Malaysia

INTRODUCING THE GEOLOGY STANDARD PROGRAM COMMITTEE (JSPG)

The Geology Standard Program Committee (JSPG) was established in early 2025 under the Board of Geologists Malaysia (BoG) as a key body responsible for overseeing academic matters related to geology education in Malaysia. Its primary aim is to ensure that geology programs nationwide are academically sound, industry-relevant, and aligned with national quality assurance frameworks.

The formation of JSPG marks a significant step forward in strengthening the governance of geology education. Its first major task is to oversee the development of the Standard Program for Geology (SP Geology)—a national academic standard that outlines the minimum learning outcomes and structure for geology degree programs. At present, the focus is on undergraduate-level programs, as advised by the Malaysian Qualifications Agency (MQA). However, JSPG is also expected to advise on postgraduate programs and other levels in the future, if required.

This effort is in line with the Malaysian Qualifications Agency Act 2007 (Act 679), which mandates the development of program standards in collaboration with professional bodies. Once the SP Geology is finalised and handed over to MQA for implementation, BoG will appoint independent evaluation panels (Panel Penilai) and a Joint Technical Committee (Jawatankuasa Teknikal Bersama, JTB). These bodies will be responsible for evaluating geology programs submitted by institutions seeking accreditation from MQA. All evaluation and technical recommendations from these panels will be submitted to JSPG, which in turn will report to the Board of Geologists Malaysia.

JSPG is chaired by Assoc. Prof. P.Geol. Dr. Mohd Rozi bin Umor (UKM), and consists of four other appointed members from academia and the geoscience industry.

To support the development of the SP Geology, JSPG established a working group known as the Geology Standard Program Development Task Force (Pasukan Petugas Pembangunan Standard Program Geologi). This task force consists of 18 members representing public and private universities offering geology programs, key industry players including PETRONAS and local geology companies, and one representative from MQA.

The task force is chaired by Assoc. Prof. P.Geol. Dr. Habibah binti Hj Jamil (UKM), with Dr. Elveane James (Universiti Malaysia Kelantan) as Deputy Chair. It reports directly to JSPG and will remain active until the SP Geology document is completed and officially submitted to MQA.

As of now, a full draft of the SP Geology has been completed, and the task force is in the process of refining the document. Feedback is currently being gathered from the public and stakeholders to ensure the standard is practical, comprehensive, and meets both academic and industry needs.

With this governance structure in place, JSPG is committed to ensuring that geology programs in Malaysia meet rigorous quality standards, produce graduates who are competent and well-rounded, and support the long-term development of the geology profession in Malaysia.

Prepared by,
Nooramiera Natasha binti Wizan
Registration Executive BoG

UPCOMING EVENTS

September 10-11, 2025: IGM International Groundwater Conference: IIGC 2025; Bangi, Selangor. More details at https://www.igm.org.my/news/150-iigc-2025.

September 16-18, 2025: The Middle East Oil, Gas and Geoscience Show (MEOS GEO); Bahrain. More details at https://www.meos-geo.com/en/home.html.

September 18-20, 2025: National Geoscience Conference (NGC) 2025; Tawau, Sabah. More details at https://www.ums.edu.my/fst/index.php/ngc-home.

September 22-23, 2025: IGM International Groundwater Conference (IIGC) 2025; Klang Valley. For details, visit https://www.igm.org.my/news/150-iigc-2025.

September 26-29, 2025: SEG 2025 Conference; Brisbane, Australia. Further information available at https://www.segweb.org/SEG-2025/SEG-Conference/SEG-2025/Home.aspx.

September 30 - October 3, 2025: International Conference and Exhibition (ICE); Rio de Janeiro. More details at https://rio2025.iceevent.org/.

October 21-22, 2025: Europe Regional Conference (ERC) 2025; Pau, France. More details at https://erc.aapg.org/2025/.

October 21-23, 2025: EAGE/ AAPG/ SEG Carbon Capture Utilisation and Storage Workshop (CCUS); Al Khobar, Saudi Arabia. More details at https://eage.eventsair.com/eageaapgseg-ccus-workshop/.

October 23-24, 2025: International Conference on Geology and Geophysics ICGG; Bali, Indonesia. Website URL: https://waset.org/geology-and-geophysics-conference-in-october-2025-in-bali.

November 3-5, 2025: EAGE/ AAPG Workshop on Tectonostratigraphy of the Arabian Plate; Riyad, Saudi Arabia. More details at https://eage.eventsair.com/eageaapg-workshop-on-tectonostratigraphy-of-the-arabian-plate-structural-evolution-of-the-arabian-basins/.

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"Earth, Energy and Environment: Navigating the Future"

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DATE: 18-20 SEPTEMBER 2025

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- Disaster Risk Reduction, Climate Hazards and Engineering Geology
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- Quaternary, Coastal and Marine Geology
- Conservation Geology, Geoarcheology and Geotourism
- Groundwater Resources and Water Security
- Geophysics, Geospatial Applications and Geotechnology
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- GUIDELINES
- Abstracts will only be accepted upon payment of conference registration fees.
- Provide 3–5 keywords relevant to your abstract.
- Authors are encouraged to present their research in English.
- The mode of presentation (Oral/Poster) will be informed upon acceptance.
- No revisions are allowed after submission.

- FORMATTING REQUIREMENTS
- *Title:*
  - Must be informative and reflective of the content.
  - Titles in Bahasa Malaysia must include an English translation.
  - Should be concise (less than 20 words) and avoid abbreviations.
- *Author's Information:*
  - Include affiliations and addresses of all authors.
  - Indicate the email address of the corresponding author.
- *Abstract:*
  - Should not exceed 300 words. Abstracts in Bahasa Malaysia must include an English translation.
  - Clearly state the subject matter, methodology, results obtained, interpretations discussed, and conclusions reached.
  - Should not contain undefined abbreviations or references.

03. CONFERENCE FEE

REGISTRATION TYPE	EARLY BIRD REGISTRATION (BY 15 JULY 2025)	LATE REGISTRATION (AFTER 15 JULY 2025)
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EXCURSION TRIP

20TH SEPTEMBER 2025

FIELD SCHEDULE

Time & Activity

08:00 AM – 09:30 AM → Travel to Southsea Gold Sdn. Bhd. (SGSB) Gold Mine
09:30 AM – 10:30 AM → Briefing on operations, geology, Q&A session and site visit to SGSB operational area
10:30 AM – 11:00 AM → Morning tea at SGSB
11:00 AM – 11:15 AM → Travel to Wullersdorf Resources Sdn. Bhd. (WRSB) Gold Mine
11:15 AM – 12:30 PM → Briefing on operations, geology, Q&A session and site visit to WRSB operational area
12:30 PM – 01:00 PM → Blasting demonstration by WRSB team
01:00 PM – 02:00 PM → Lunch at WRSB
02:00 PM – 03:00 PM → Travel to Columnar Basalt Balung Cocos
03:00 PM – 04:00 PM → Site visit to Columnar Basalt Balung Cocos
4:00 PM → Return back to Borneo Royale Hotel

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CPD: 3 CPD Points

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PRE-CONFERENCE WORKSHOP

"Integrated Geothermal Short Course: Resource Assessment of Tawau and Power Conversion Systems for Volcanic & Granitic Settings"

P. GEOL. FREDOLIN JAVINO
JABATAN MINERAL & GEOSAINS MALAYSIA (DEPARTMENT OF MINERAL & GEOSCIENCE MALAYSIA)

Geoscientific Techniques - Isotope, Geochemical, Geological & Geophysical Methods

GEOFFROY PAIXACH
CFG GEOTHERMAL, FRANCE

Integrated Approaches to Geothermal Energy Conversion and Engineering

- VENUE: BORNEO ROYALE HOTEL, TAWAU, SABAH
- DATE: 17 SEPTEMBER 2025
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- REGISTRATION FEE: RM 50
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  BANK: STANDARD CHARTERED BANK
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The title must be informative and reflects the content of the paper. It should be concise (less than 20 words). Avoid using abbreviation in the title. Titles in Malay should include an English translation.

Author's Address

Affiliations, address, and email of all authors must be provided. The addresses should be sufficient for correspondence.

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Abstracts in Malay (optional for manuscripts in English) and English, each in one paragraph and should not exceed 300 words, is mandatory. It should clearly identify the subject matter, results obtained, interpretations discussed, conclusions reached and significance of the study. The abstract should not contain any undefined abbreviations or references.

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Chapter of book and Symposium volume:
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Article in Malay:
Lim, C.H. & Mohd. Shafeea Leman, 1994. The occurrence of Lambir Formation in Ulu Bok Syncline, North Sarawak. Bulletin of the Geological Society of Malaysia, 35, 1-5. (in Malay with English abstract).

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PERSATUAN GEOLOGI MALAYSIA

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