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## Editorial note

# Contributing geological knowledge for sustainable development

The Bulletin of the Geological Science of Malaysia is a peer-reviewed open access interdisciplinary Earth Science journal. Over the decades, the Bulletin has documented about 1400 articles covering trending research topics and original findings in geology that contribute both directly and indirectly to sustainable development. Areas covered include economic geology, engineering geology, environmental geology, geochemistry, geological heritage, geomorphology, geophysics, hydrogeology, mining geology, palaeontology, petroleum geology, regional geology, sedimentology, stratigraphy, structural geology and tectonics. While the geographic focus is primarily Malaysia and Southeast Asia, comparative studies from other regions that are of current interest and have potential impact on sustainable development are also considered important. This includes findings related to oil and gas, mining, environmental management, heritage conservation, geotourism, earthquake and hazard assessment, disaster risk reduction and climate change.

It is a pleasure to present to you the 76$^{th}$ volume of the Bulletin of the Geological Society of Malaysia that comprises seven articles. The lead article by Dobbs *et al*. (2023) is relevant to the United Nations Sustainable Development Goal 11 (SDG 11) on Sustainable Cities and Communities. The following two articles by Fauzi *et al*. (2023) and Kadri *et al*. (2023) contribute to SDG 9 on Clean and Affordable Energy as well as SDG 13 on Climate Action. The article by Raj (2023) is rooted in the field of engineering geology. The remaining articles by Kessler & Abdullah (2023), Madon & Jong (2023) and Breitfeld *et al*. (2023) draw on multiple fields of geology such as regional geology, sedimentology, stratigraphy and tectonics. All these articles document geological knowledge that indirectly support sustainable development.

Dobbs *et al.* (2023) present the first three-dimensional geological model of Kuala Lumpur, delivered by a consortium of geoscientists from government, industry and academia. A workflow has been established to transform conventional hard copy borehole information augmented by surface data into a conceptual 3D model using open-source software. The modelling process revealed gaps in geological knowledge and data that hinder sustainable and resilient urban development in Kuala Lumpur. Significant expansion of the borehole database by acquiring current and future site-investigation records as well as implementation of a coordinated city-scale ground investigation programme with all relevant stakeholders have been suggested to address the gaps. The workflow offers a cost-effective and robust starting point for obtaining useful three-dimensional geological models for countries with limited access to information and resources. These models serve to enhance understanding of non-geoscience decision-makers regarding subsurface risks and benefits in planning and managing the expansion of cities. They also underscore the contribution of geology to SDG 11, to make cities and human settlements inclusive, safe, resilient and sustainable.

Fauzi *et al*. (2023) reports on the rare earth element (REE) deposit and its enrichment patterns in Bukit Enggang Granite, Kedah. Geochemical analysis revealed that the deposit is of the ion adsorption-type, with REE enrichment in weathered profiles originating from easily weathered REE bearing minerals in the parent rock. The enrichment is due to the dissolution of soluble REE-bearing minerals such as fluorapatites and fluorocarbonates in the upper, oxidized parts of the profiles, and adsorption of dissolved REEs onto the lower clays. Geochemical sampling beyond the depth of 5 m and the use of geophysical methods have been suggested to determine the actual depth of the REE deposit in the area. The demand for clean energy and new technologies including batteries have contributed to increasing demand for REE worldwide. REE deposits from the ion-adsorption clays have relatively lower radioactive levels and are commonly referred to as non-radioactive rare earth elements (NR-REE). In Malaysia, NR-REE is classified as a strategic mineral for the country. This calls for further investigation of the findings from this area.

Kadri *et al*. (2023) deployed integrated geochemical and geophysical methods to identify geothermal prospects in Siogung-Ogung, North Sumatra, Indonesia. The geochemical survey involved the determination of geothermometers silica ($SiO_2$), Na-K and Na-K-Ca, to determine the temperature of the potential geothermal reservoir. Two-dimensional electrical resistivity and geomagnetic methods were used to identify and characterise the prospects. The findings indicate a reservoir temperature of 572°C and presence of material, possibly andesite, which can potentially act as a carrier for

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geothermal fluid flow. The integration of these results warrants further investigation of this prospect in Siogung – Ogung for geothermal energy. This is of great significance to Indonesia, specifically North Sumatra, which suffers from a chronic shortage of energy sources.

Raj (2023) continues to build on the physical characterization of the weathering profile over rhyolite at km 38.2 of the Kuala Lumpur – Karak Highway in Peninsular Malaysia. The concentric stages of weathering that develop around core-stones at the weathering profile are further elaborated to define more clearly the transition between 'rock' and 'soil' in weathering of the rhyolite. Weathering starts with the exposure of grain boundaries and micro-cracks, followed by dark brown staining and subsequent alteration of plagioclase feldspar groundmass grains and phenocrysts to sericite and clay minerals. Biotite flakes are then bleached and altered to chlorite and clay minerals, followed by the alteration of groundmass alkali feldspar grains to sericite and clay minerals. The final stage involves alteration of alkali feldspar phenocrysts. Quartz grains remain unaltered but break-apart and diminish in size due to continual opening-up of grain boundaries and micro-cracks. The transition between 'rock' and 'soil' occurs when all plagioclase groundmass grains and phenocrysts, all alkali feldspar groundmass grains, and most phenocrysts are altered. The rock - soil transition is gradational in nature as shown by decreasing values of dry unit weight, dry density and uniaxial compressive strength, but increasing apparent porosity. The last weathering stage is marked by large apparent porosities (>14%) but low values of dry unit weight (<21.90 kN/m$^3$) and dry density (<2,232 kg/m$^3$).

Kessler & Abdullah (2023) introduce a multi-disciplinary approach drawing on geochemical characteristics, seismic imaging, structural elements and regional geology to examine uplift and erosion in the Miri area of northwest Sarawak. A combination of vitrinite reflectance data and material balancing suggests a regional uplift in the Neogene affecting the entire coastal area, and a tectonically focused uplift linked to rise of anticlinal structures during the Upper Pliocene. The findings shed light on the petroleum system and hydrocarbon accumulation within the Miri area, which is largely intact only in the Siwa-Seria anticlinal trend. The importance of overburden in relation to depth of burial and thermal requirements for maturing source rocks capable of generating hydrocarbons is highlighted.

Madon & Jong (2023) provide further insights into the subsidence history of Sarawak Basin, which lies mainly offshore beneath the broad shelf north of Sarawak. The assessment is based on stratigraphic data from a selection of exploration wells that have been updated with the biostratigraphic framework from a previous study. A multi-phase history of crustal extension (rifting), subsidence and uplift is interpreted. The complex subsidence history of Sarawak Basin, which is similar to surrounding areas suggests a shared link to the rifting and spreading histories of the South China Sea basin and their interactions with Northwest Borneo.

Breitfeld *et al*. (2023) document findings from the fieldwork undertaken on a Triassic turbidite succession from the Kuching area, Sarawak. The study also draws on age data and provenance of the strata from previous work, and age relationships with other rock-types. It has been recommended that the Triassic sedimentary and meta-sedimentary slope deposits in the area be called the Kuching formation. The formation comprises thinly-bedded stacked turbidites, consisting of incomplete Bouma sequences, with multiple, erosive channel sandstone bodies deposited under upper flow regime waning flows. Thin debrites with abundant coaly-material are interbedded with the channel sandstones. Unfortunately, poor exposure and removal of outcrops makes it challenging to assign a type-section. Notwithstanding, the findings sheds light on the poorly investigated pre-Cretaceous history of Borneo.

Joy Jacqueline Pereira
Editor