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EVALUATION ON GEOHERITAGE POTENTIAL OF THE LOJING-GUA MUSANG ROAD, KELANTAN

Choong Chee Meng[1,2*], Nicole Wong Yeng Xin[1], Yayu I. Arifin[3], Ronal Hutagalung[3], Novriyanto Napu[3], Atilia Bashardin[4], Noorzamzarina Sulaiman[5], Tan Yan Eng[6], Muhammad Aslam Md Yusof[6]

[1] Department of Geosciences, Universiti Teknologi PETRONAS, Malaysia
[2]Digital Geoscience Global Sdn Bhd
[3]Universitas Negeri Gorontalo, Indonesia
[4]Jabatan Mineral dan Geosains Malaysia Kelantan, Malaysia
[5] Department of Geosciences, Universiti Malaysia Kelantan, Malaysia
[6]Department of Petroleum Engineering, Universiti Teknologi PETRONAS, Malaysia

*Email: cheemeng.choong@gmail.com

ABSTRACT

The Lojing-Gua Musang road runs through outcrops that are home to various species of flora and fauna. The road also exposes several lithologies, including those from the Bentong-Raub Suture Zone and the Main Range granite. The area has significant geoheritage values that make it suitable to be geosites. The study aimed to evaluate the potential of the selected localities as geosites based on their educational/scientific, aesthetic/scenic, protection values and public safety. The geoheritage potential assessment was divided into two phases: (1) data gathering for the potential geosite and (2) evaluation using a scoring rubric of the Geosite Assessment Model (GAM). The sites assessed were Gunung Swettenham, Sungai Ber Hot Spring, Pos Blau brecciated limestone, and Pos Blau bedded chert. The assessment results showed that Gunung Swettenham and Sungai Ber Hot Spring had higher scores due to their aesthetic values and better protection. Brecciated limestone and bedded chert in Pos Blau area had lower scores in most of the categories of this assessment. To improve the quality of these potential geotourism spots, the study recommends the construction of basic infrastructures, including parking lots, information boards, proper pavement to the interest points, electronic monitoring devices, lighting systems, and security boundaries. Overall, the study suggests that with proper development, these geosites have the potential to attract tourists and promote geotourism in the area.

Keywords: *Geosite, geoheritage, Geosite Assessment Model, Lojing*

INTRODUCTION

Geoheritage emphasises the unique characteristics and representativeness of the geosites towards geology and its place in modern culture. The awareness of the importance of geo-conservation has sprouted internationally for the past decade and acts as a possibility to promote geoheritage-linked activities such as geotourism [1]. Geotourism can enhance economic growth and employment, especially in rural areas. Furthermore, it can act as the primary tool for preserving and raising awareness of the environment [2]. Malaysia is well known for its "Malaysia Truly Asia" tourism campaign that promotes the diversity of nature's beauty and cultures by establishing geoheritage and geopark. At the international level, Langkawi of Malaysia has been recognised as UNESCO Global Geopark; Lenggong Valley, Malacca & George Town, Gunung Mulu National Park and Kinabalu Park are currently

the World Heritage of UNESCO. In the past few years, Malaysia has established national-level geoparks, such as Kinta Valley Geopark, Jerai Geopark, Kinabalu Geopark, Gombak-Hulu Langat Geopark and Stong Geopark. These areas have been developed with careful planning, which takes into consideration the socio-economy, culture and conservation. However, most places in Malaysia are still under exploration for their geoheritage values. The detailed geoheritage assessment can discover more values which may contribute to tourism, education and conservation.

Situated in the southwestern region of Kelantan, Malaysia, Lojing is a hilly terrain located in the Gua Musang district, adjacent to the Cameron Highlands in Pahang, as shown in Figure 1. The road that connects Lojing to Gua Musang town features a series of roadcuts exposing a diverse range of rock types and provides access to several natural attraction sites. Given the area's rich geological features and proximity to natural wonders, there is a strong potential for the Lojing-Gua Musang region to be recognised as a national-level geopark.

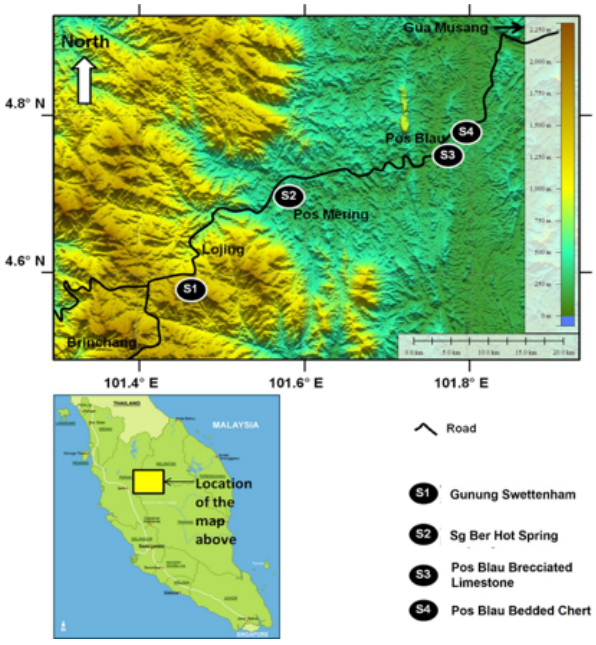


Figure 1 Topographic map and selected sites (S1 - S4) for geosite assessment in the Lojing-Gua Musang area

GEOLOGICAL SETTING OF LOJING AREA

Lojing area is located on the eastern flank of the Main Range, Peninsular Malaysia. The area features exposed rocks of the Bentong-Raub Suture Zone and Main Range granite along the Lojing-Gua Musang road.

The Bentong-Raub Suture Zone in Peninsular Malaysia characterises the closure of the Devonian-Triassic Paleo-Tethys oceanic basin. It cuts across entire Peninsular Malaysia and is defined as an N-S trending belt of a metamorphosed oceanic succession. The large diversity of crustal materials accreted and exposed along the edge of the Sibumasu continent, including metamorphic rocks (amphibolite, mica schist, carbonaceous schist, quartzite and phyllite), sedimentary rocks (chert, mudstone, sandstone and minor limestone and conglomerate) and volcanic rocks (andesitic-basaltic), melange/olistrostome units and minor serpentinite [3]. The chert of the suture zone occurs in white, grey, red and black colour variations and is often thinly bedded with mudstone. The studies on radiolaria from the chert of Bentong-Raub Suture Zone show a Late Devonian to early Middle Permian age and are inferred to represent the age of oceanic spreading [4]-[5]. Some of the fossils within the same age range were also extracted from the chert and limestone clasts within the mélange units supporting the dating of the rocks [3] and [5]-[9].

A major granitoid province named the Main Range Province is found next to the Paleo-Tethys sutures stretching from Thailand to Peninsular Malaysia [10]. After the Paleo-Tethys was completely consumed, the S-type granite dominated the Main Range, Province resulted in the Sibumasu-Indochina collision. Most of the radiometric ages of the S-type granite are Late Triassic [10]-[12]. In Peninsular Malaysia, the Main Range Province granite forms a nearly N-S trend batholith. The granitoids are mostly porphyritic biotite granites with K-feldspar phenocrysts and minor hornblende-biotite adamellites [13]. The Main Range Province granite has a crustal-source origin supported by peraluminous and potassic characteristics, a high level of incompatible and high field strength elements with high initial 87Sr/86Sr ratios (0.7105–0.7310) [14]. The K-Ar and Rb-Sr ages of the Main Range granites are within the Late Triassic, while the higher precision U-Pb age of the granites are concentrated within the same time range, i.e., 214–226Ma [14]-[17].

METHODOLOGY

The study was carried out in two phases: phase 1 consists of data gathering and general characterisation of the potential geosites; phase 2 is a geosite assessment in different aspects of the site (Figure 2).

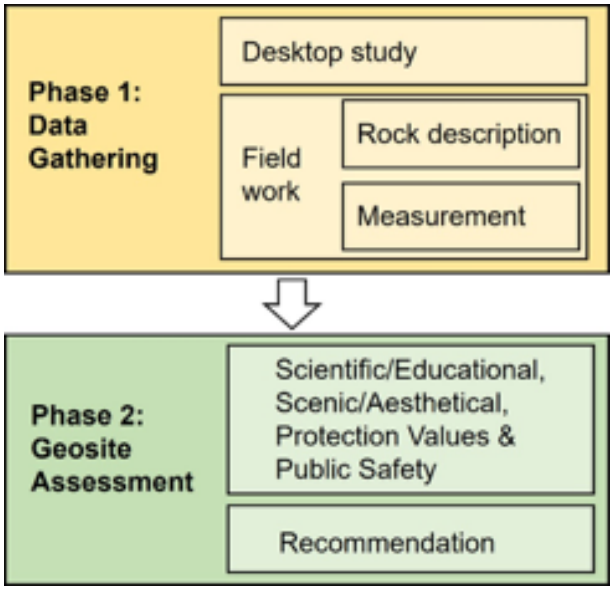


Figure 2 Scope and flow of the assessment of the potential geosites in the study

Data Gathering

Multiple sources were consulted to gather information on prospective geosites through desktop research. Once the prospective geosites are selected, conventional fieldwork is conducted to visit all sites for data collection. The mineralogy and petrography of the rock will be recorded. The orientation of the structures formed on the rocks, such as bedding, foliation, fracture and faults, will be measured, and their details will be described. The collected lithological information will be compiled and plotted on a map. Data on geomorphology, geography, facilities and socio-economic information relevant to tourism will also be collected, systematically organised and assessed to facilitate an advanced evaluation.

Geosite Assessment

Four representative geosites were selected after conducting desktop and field studies. The second phase is the quantitative assessment, where the sites were assessed using the modified Geosite Assessment Model (GAM) developed by Vujicic et al. [18]. The assessment will mainly focus on evaluating the sites' Main Values (MVs), which include Scientific/ Educational (VSE), Scenic/Aesthetical (VSA), and Protection Values (VPr). The VSE value considers the rarity, representativeness, knowledge of geoscientific issues and level of interpretation of the sites. The VSA value emphasises the viewpoints, surface, surrounding landscape and nature, and environment fitting of the sites. The VPr value evaluates each site's current condition, protection level, vulnerability, and suitable visitor number. This additional parameter (VPS) has been added to the Geosite Assessment Model of Vujicic et al. [18] for this study to ensure public safety. This parameter assesses each site's security management (VPS1) and surrounding environmental hazards (VPS2). To summarise, the geosite assessment considered fourteen elements, as mentioned above. The weight of each element is based on its definition as presented in the GAM (Table 1) and ranges from 0 to 1 (five grades).

Table 1 Geosite assessment model's (GAM) score sheet [18]

Main Value	Description	Grade				
Scientific/ Educational value (VSE)		**0**	**0.25**	**0.5**	**0.75**	**1**
Rarity (VSE_1)	Number of localities in immediate surroundings.	Common	Regional	National	International	The only occurrence
Representativeness (VSE_2)	Didactic and exemplary characteristics of the site due to its own quality and general configuration (Perreira, 2007)	None	Low	Moderate	High	Utmost

Knowledge of geoscientific issues (VSE_3)	Number of written papers in acknowledged journals, thesis, presentations and other publications	None	Local publications	Regional publications	National publications	International publications
Level of interpretation (VSE_4)	Level of interpretive possibilities on geological and geomorphologic processes, phenomena and shapes, and scientific knowledge.	None	Moderate level of processes but hard to explain to non-experts	Good example of processes but hard to explain to non-experts	Moderate level of processes but easy to explain to common visitor	Good example of processes and easy to explain to common visitor
Scenic/ Aesthetic (VSA)		**0**	**0.25**	**0.5**	**0.75**	**1**
Viewpoints (VSA_1)	Number of viewpoints accessible by a pedestrian pathway. Each must present a particular angle of view and be situated less than 1 km from the site.	No	one	two to three	four to six	More than six
Surface (VSA_2)	Whole surface of the site. Each site is considered in quantitative relation to other sites.	Small	–	Medium	–	Large
Surrounding landscape and nature (VSA_3)	Panoramic view quality, presence of water and vegetation, absence of human-induced deterioration, vicinity of urban area, etc.	–	Low	Medium	High	Utmost
Environmental fitting of sites (VSA_4)	Level of contrast to nature, contrast of colours, the appearance of shapes, etc.	Unfitting	–	Neutral	–	Fitting
Protection (VPr)		**0**	**0.25**	**0.5**	**0.75**	**1**
Current condition (VPr_1)	The current state of geosite.	Totally damaged (as a result of human activities)	Highly damaged (as a result of natural processes)	Medium damaged (with essential geomorphologic features preserved)	Slightly damaged	No damage

Protection level (VPr_2)	Protection by local or regional groups, national government, international organisations, etc.	None	Local	Regional	National	International
Vulnerability (VPr_3)	Vulnerability level of geosite	Irreversible (with possibility of total loss)	High (could be easily damaged)	Medium (could be damaged by natural processes or human activities)	Low (could be damaged only by human activities)	None
Suitable number of visitors (VPr_4)	Proposed number of visitors on the site at the same time, according to surface area, vulnerability, and current state of geosite.	0	0 to 10	10 to 20	20 to 50	More than 50
Public Safety (VPS)		**0**	**0.25**	**0.5**	**0.75**	**1**
Security (VPS_1)	Security management, i.e. visibility at nighttime and interpersonal surveillance.	Not covered with a lighting system. Obstructed view with no crowd.	Not covered with a lighting system. Partially obstructed view with some crowd.	Partly covered with a lighting system. Partially obstructed view with some crowd.	Fully covered with a lighting system. Partially obstructed view and enough surrounded crowd.	Fully covered with a lighting system.
Surrounding environment hazard (VPS_2)	The access and the geosites are clear from hazards, i.e. steep slopes, falling objects, and slippery surfaces.	Extremely likely to be exposed to hazards.	Likely to be exposed to hazards.	Moderate chance of exposure to hazards.	Unlikely to have hazards.	None

RESULTS AND DISCUSSION

Description and Assessment of the Selected Sites along Lojing – Gua Musang Road

The map in Figure 3 displays the geological map of the Lojing-Gua Musang road, which includes four specific sites: Gunung Swettenham (S1), Sungai Ber Hotspring (S2), Pos Blau brecciated limestone (S3), and Pos Blau bedded chert (S4).

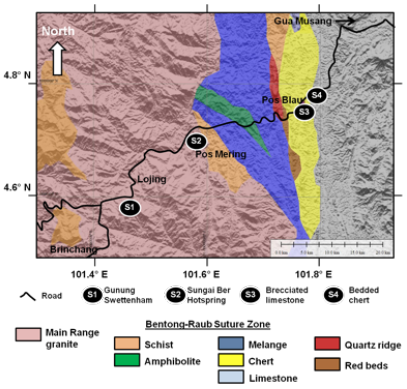


Figure 3 Lithology distribution along Lojing -Gua Musang road and the locations of four geosites

Gunung Swettenham (S1)

Gunung Swettenham (coordinate: 4.595867, 101.433341) stands at an impressive elevation of 1,961 meters at the Pahang and Kelantan state border. This mountain serves as one of the popular hiking trails in the Cameron Highland area, offering visitors the chance to explore both urban vegetable farms and natural forest areas that are equally appealing to tourists (Figure 4). The high elevation of the forest area has resulted in a range of mossy fauna, while other sections of the trail expose visitors to granitic rock formations with coarse-grained minerals like quartz and feldspar, providing a unique learning opportunity for those interested in geology. Based on the characteristics mentioned above, the hiking trail of Gunung Swettenham is proposed to be a geosite.

Figure 4 The view is from the starting point of Gunung Swettenham hiking trail (S1) located in front of the Biodiversity Centre, Forestry Department of Kelantan State (Photo by Sagahayat [19])

In terms of scientific/educational value (VSE), this site has a common rarity (VSE_1: 0 mark), low representative (VSE_2: 0.25 mark), has been introduced by local publication (VSE_3: 0.25 mark) and moderate level of geological processes but easy to explain to the common visitor (VSE_4: 0.75 mark). For the category of scenic/aesthetic (VSA), it has four to six viewpoints (VSA_1: 0.75 mark) along the trail, small to medium size of surface (VSA_2: 0.25 mark), medium level of surrounding landscape and nature (VSA_3: 0.5 mark) and well environmental fitting of sites (VSA_4: 1 mark). As the protection (VPr) of the site, its current condition is not damaged (VPr_1: 1 mark), with the national level of protection (VPr_2: 0.75 mark), low vulnerability level of the site (VPr_3: 0.75 mark) and suitable for 10-20 visitors present at the same time (VPr_4: 0.5 mark). The hiking area of Gunung Swettenham is remote, with no proper lighting system (VPS_1: 0.25 mark), and the inclined hiking path could be slippery on rainy days (VPS_2: 0.5 mark). The infrastructures such as pavement, staircase for the steep cliff, and directory signage of this site are necessary to improve the tourist experience.

Sungai Ber Hot Spring (S2)

Sungai Ber Hot Spring (coordinate: 4.71016, 101.56820), situated in the Main Range of Peninsular Malaysia, is one of the many hot springs present in the region. The hot spring can be found in a granitic area situated approximately 300 m away from the main road. The granite in this region is medium- to fine-grained and highly fractured (Figure 5). Another hot spring location, Sungai Mering, is in the vicinity and is also in fractured granite, as Kamal et al. [20] reported. According to Baioumy et al. [21], the occurrence of these hot springs is related to post-magmatic activities. The surface spring water temperature at Sungai Ber Hot Spring can reach up to 72°C.

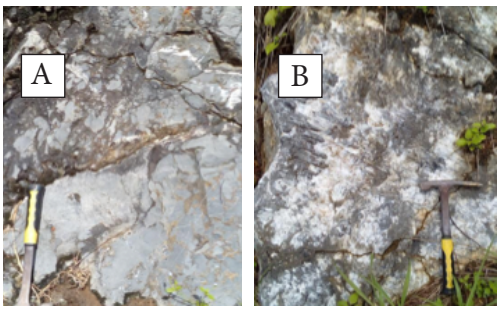
Figure 5 The Sungai Ber Hot Spring (S2) occurred in the fractured granite, and the hot water continuously seeps out from the granite fractures. The hot spring area covers about 1300 m^2, and this site is approximately 340 m from the main road, Jalan Gua Musang-Cameron Highlands, with proper road access

For the scientific/educational value (VSE), this site has been rated as a regional rarity (VSE_1: 0.25 mark) due to not having many similar occurrences nearby, low representative (VSE_2: 0.25 mark), the relevant study has been published in regional publication (VSE_3: 0.5 mark) and a moderate level of geological processes but easy to explain to the common visitor (VSE_4: 0.75 mark). In the category of scenic/ aesthetic (VSA), it has two to three viewpoints (VSA_1: 0.5 mark), including the view at the nearby riverside, medium to large size of surface (VSA_2: 0.75 mark), it has a high surrounding landscape and nature (VSA_3: 0.75 mark), and medium

to the fitting level of the site to surrounding natural environment (VSA_4: 0.75 mark). As the protection (VPr) of the site, it had the recent upgrades in infrastructure and was not damaged (VPr_1: 1 mark), with the national level of protection (VPr_2: 0.75 mark), low vulnerability level of the site (VPr_3: 0.75 mark) and suitable for 20-50 visitors present at the same time (VPr_4: 0.75 mark). For public safety, security is considered low with no proper lighting at night (VPS_1: 0.25 mark), and the high-water temperature and slippery floor surface could be a hazard to visitors (VPS_2: 0.25 mark).

Pos Blau Brecciated Limestone (S3)

Limestone is a minor occurrence of Bentong-Raub Suture Zone. A highly fractured limestone outcropped at a 50 m long roadcut section of Pos Blau (coordinate: 4.75697, 101.75956). The limestones show abundant shearing evidence and occasional brecciated texture. The clasts found in the breccia are commonly a few cm in length and angular in shape (Figure 6a). The secondary structure found in the limestone is faults. The right-lateral strike-slip faults are common here, and they have N-S strike with nearly vertical dip, indicated by sharp slicken-lines (Figure 6b). The brecciated texture and brittle faulting show the occurrence of strong deformation in limestone. Some calcite minerals on fault planes (slickenfibre) are also developed into a perfect crystal shape, typical examples of geological elements. Thus, this spot carries a high value in education/ learning purposes for both academics and the public.



[a] Brecciated limestone composed of angular clasts
[b] The fault plane is marked with striation and slick fibres

Figure 6 Pos Blau Brecciated Limestone (S3)

In the rating of scientific/educational value (VSE), this site is given common rarity (VSE_1: 0 mark) due to common occurrences of limestone in Malaysia, low representative (VSE_2: 0.25 mark), the relevant study was published in a local publication (VSE_3: 0.25 mark), and it is showing a good example of processes but hard to explain to non-experts (VSE_4: 0.5 mark). For the value of scenic/ aesthetic (VSA), it has only one view point (VSA_1: 0.25 mark), small size of surface (VSA_2: 0 mark), low level surrounding landscape and nature (VSA_3: 0.25 mark) and, neutral fitting of the site to surrounding natural environment (VSA_3: 0.5 mark). As the protection (VPr) of the site, it has a medium level of damage (VPr_1: 0.5 mark), with no specific protection on this site (VPr_2: 0 mark), medium vulnerability level of the site which natural processes or human activities could damage (VPr_3: 0.5 mark) and the current situation of the site only allowed 0-10 visitors present at a time (VPr_4: 0.25 mark). The outcrop is located behind a waist-line height barrier wall across drainage (VPS_1: 0.25 mark), and the possibility of surrounding environment hazards such as dipping surface is considered moderate (VPS_2: 0.5 mark). This locality is at the roadside, which is easy to spot by road travellers. However, the staircase will be necessary for the visitors to access the rock exposure.

Pos Blau Bedded Chert (S4)

Chert is a sedimentary rock made up of microcrystalline quartz. A sequence of thinly interbedded chert with mudstone is cropped out at the Pos Blau's roadside (coordinate: 4.775810, 101.779219) (S4) (Figure 7). The outcrop is about 50 m long and 3-5 m in height. The cherts are grey to pinkish coloured. The individual chert layers are commonly a few centimetres thick, and mudstone is generally thin, i.e. less than 1 cm thick. The radiolaria fossils have been discovered in this sequence with the age of Early Sakmarian [22]. The interbedded chert and mudstone is also an important unit of Bentong-Raub Suture Zone and witnessed the presence of the ancient Paleo-Tethys ocean.

For the scientific/educational value (VSE), this site has a regional-level of rarity (VSE_1: 0.25 mark) due to localised occurrences of fossilised cherts in Malaysia, moderate representative (VSE_2: 0.5 mark), the relevant study published in a national publication (VSE_3: 0.75 mark) and it is showing a good example of processes but hard to explain to non-experts (VSE_4: 0.5 mark). In the rating of the value of scenic/ aesthetic (VSA), it has only one view point (VSA_1: 0.25 mark), small to medium size of surface (VSA_2: 0.25 mark), low level surrounding landscape and nature (VSA_3: 0.25 mark) and, neutral fitting of the site to surrounding natural environment (VSA_3:0.5 mark). As the protection (VPr) of the site, it has a minor level of

damage (VPr_1: 0.75 mark) because of its high resistance to weathering, with no specific protection on this site (VPr_2: 0 mark), low vulnerability level of the site which could be damaged only by human activities (VPr_3: 0.75 mark) and the current situation of site only allow 10-20 visitors to present there at the same time (VPr_4: 0.5 mark). The public safety at this location has a score of 0.5 mark for security (VPS_1) as it is along the roadside, and the topography is relatively low (VPS_2: 0.75 mark). This site is one of Malaysia's outcrops of fossilised cherts and is worth adopting as a locality for knowledge of Earth's history.

Figure 7 Thinly interbedded chert and mudstone in the Pos Blau area (S4)

Discussion on Potential Geosites in Lojing-Gua Musang Road

The results of the Geosite Assessment Model (GAM) evaluation of four potential geosites located in the Lojing area is shown in Table 2. The total scores of geosite assessment for each site are 8.00/14 (Gunung Swettenham, S1), 8.25/14 (Sungai Ber Hot Spring, S2), 4.00/14 (Pos Blau brecciated limestone, S3) and 6.50/14 (Pos Blau bedded chert, S4).

S1 and S2 have relatively higher scores of GAM due to their higher aesthetic values (i.e. good surrounding landscape and nature, as well as better environmental fitting of sites) and better protection (no significant damage of sites and low vulnerability level). S3 and S4 have lower scores of GAM mainly due to the sites not yet established as visiting spots lacking viewpoints, the limited size of visiting surface, and the low-level surrounding landscape and nature (partly due to the extensive oil palm plantation).

More scientific research and international publication on the sites (S2, S3 and S4) will also help to increase the knowledge on geoscientific issues (VSE_3), which may help to discover new significant geological uniqueness of the sites. Then, it may become one of the attractions to the visitors. All sites are not well equipped with necessary infrastructures, except S2 has a proper access path from the main road to the hot spring and a roofed resting point. To improve the quality of potential geosites as the geotourism spots, the basic infrastructures such as parking lots, information boards and proper pavement to the interesting point of the sites need to be constructed.

CONCLUSION

The Lojing-Gua Musang road is next to a reserved forest, exposing various rock types and with hot springs. Those characteristics make this area a suitable candidate for geoheritage or geosites. Four selected sites along this area, i.e., Gunung Swettenham (S1), Sungai Ber Hotspring (S2), Pos Blau brecciated limestone (S3) and Pos Blau bedded chert (S4), have been assessed on their geosite potential. The total scores of geosite assessment for each site are 8.00/14 (Gunung Swettenham, S1), 8.25/14 (Sungai Ber Hot Spring, S2), 4.00/14 (Pos Blau brecciated limestone, S3) and 6.50/14 (Pos Blau bedded

Table 2 The scores of the Geosite Assessment Model (GAM) for the sites in Lojing-Gua Musang Road

Site	VSE				VSA				VPr				VPS		Total /14
	VSE_1	VSE_2	VSE_3	VSE_4	VSA_1	VSA_2	VSA_3	VSA_4	VPr_1	VPr_2	VPr_3	VPr_4	VPS_1	VPS_2	
S1	0	0.25	0.25	0.75	0.75	0.25	1	1	1	0.75	0.75	0.5	0.25	0.5	8.00
S2	0.25	0.25	0.5	0.75	0.5	0.75	0.75	0.75	1	0.75	0.75	0.75	0.25	0.25	8.25
S3	0	0.25	0.25	0.5	0.25	0	0.25	0.5	0.5	0	0.5	0.25	0.25	0.5	4.00
S4	0.25	0.5	0.75	0.5	0.25	0.25	0.25	0.5	0.75	0	0.75	0.5	0.5	0.75	6.50

chert, S4). S1 and S2 scores are relatively higher due to their higher aesthetic values and better protection. Further scientific research and international publication on the sites are recommended to help enhance the geoscientific knowledge and to find new values to attract visitors. Besides, the basic facilities (i.e., car park, information boards and proper pavement connecting to the sites, security monitoring, safety sign board and boundary) are required to improve the quality of potential geosites as geotourism sites.

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