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Geological Review of the Rafflesia Trail, Near Kampung Jedip, Lojing Highlands: Inputs for a Nature-Based Tourism Site in Kelantan, Malaysia

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Abstract

A geological review was performed in the *Rafflesia* Trail, near Kampung Jedip, in Lojing Highlands, Kelantan, Malaysia. This area is famous for its *Rafflesia* and has become one of tourism attractions in the state of Kelantan. However, the recent rampant agricultural activities have significant effects to the area. The objective of this study is to give substantial geological inputs in terms of geomorphology, lithology, structural features, and geohazard potentials in the study area. Desk study was conducted by reviewing some literatures related to the topic and the study area. Field work was organized during a scientific expedition in January 2014 to collect data, samples, and photographs. Geomorphologically, the study area is mountainous area which mostly consists of mountain ridges and mountain valleys. Some fluvial features occur in the study area, such as waterfalls, cascades, rapids, runs, pools, potholes, lateral bars, and point bars. This area is composed of granitic rocks, mostly porphyritic granite, and covered by superficial Quaternary deposits. The geological structure that is commonly found in the study area is joints, where they divide the rock body into large, roughly angular blocks, which is called as brecciation. The potential geohazard in the study area is landslides, where some of them are composed of soil only and some others are mixtures of rock and soil. This study recommends this area should be supported as a sustainable nature-based tourism site in Lojing Highlands, Kelantan.

1. Introduction

A geological review was carried out in the Rafflesia trail and its vicinity, in the area of Sungai (river) Denkong, Lojing Highlands, in the state of Kelantan, Malaysia. Lojing highlands are one of forest reserve areas in Kelantan and so far well-known as the home for Rafflesia kerri (Zulhazman Hamzah et.al., 2010; Siti Munirah, 2012), one of the biggest flowers in the world and the largest species in Peninsular Malaysia. The Rafflesia has become the icon and the main tourism attraction of the highlands. However, the development of agricultural activities has prompted the deforestation in the highlands. As the result, soil erosions, landslides, and other environmental impacts occur extensively in many parts of the highlands.

The present research includes reviews on geomorphology, lithology, structural features, and geohazard potentials of the study area. This study aims to give inputs to the geological conditions and potential hazards in the study area, and thus, to support the conservation of the area for sustainable nature-based tourism development.

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1.1. Study Area

The study area is along the *Rafflesia* Trail near the settlement of aboriginal people (*orang asli*) of Temiar ethnic in Kampung Jedip, Lojing Highlands, around 15 km from Cameroon Highlands, a famous tourism destination in the neighbouring state of Pahang. This area is located at the foot of the Main Range and is covered with the highland tropical rainforest which is rich of flora, fauna, and local communities who live harmoniously with the nature. So, beside *Rafflesia*, this area has more to offer, either biotic or abiotic components and all these will attract scientists and tourists from both domestic and international.

This study was focused in the *Rafflesia* trail along Sungai Denkong, near Kampung Jedip, Lojing Highlands (Figure 1). This study area is just near the settlement for the aboriginal people of Temiar community and is located within the Sungai Beruk Reserve Forest. The study area is close to the Kelantan – Perak border in the west, and Kelantan – Pahang border in the south. To get to the study area, the excellent road network i.e. the Gua Musang – Lojing – Cameroon Highlands Highway is provided to link Lojing with other areas. Up to 30 tourists visit the site daily, mainly for observing the *Rafflesia* (Dony Adriansyah et.al., 2014; Figure 2)

2. Materials and Methods

Materials of the research include map, photographs and literatures related to the study area and some geological studies, such as geomorphology, lithology, structural features as well as geohazard potentials. Some standard geological equipments such as GPS, compass, hammer etc. were brought and used during the field work. The methods used for this study were generally divided into two, i.e. desk study and field study. Desk study required efforts to perform literature study about the topic and the study area. Meanwhile, field study was conducted through field investigations in some locations in the study area (Appendix A). The investigation was part of a scientific expedition in Lojing Highlands organized by Faculty of Agro-based Industry and Faculty of Earth Sciences, Universiti Malaysia Kelantan in January 2014. Geological and geomorphological surveys, rock sampling, some measurements, and photograph shoot were conducted during the expedition.

3. Results and Discussion

3.1. Geomorphology of Study Area

The geomorphology of study area is related to the geomorphology development of Peninsular Malaysia. Although the Peninsula is considered to have been relatively stable tectonically, it has still been influenced by regional events of Sundaland. Its present-day landforms thus result in part from its prolonged sub-aerial exposure throughout the Tertiary period, with predominance of weathering and erosion. The study area is situated in Lojing Highlands of southern Kelantan, which is a part of the Main Range (Figure 3), the “backbone” of Peninsular Malaysia and the most prominent mountain range in the Peninsula (Dony Adriansyah et.al., 2014). This mountain range extends from southern Thailand in the north to Negeri Sembilan in the south, with the elevations rarely less than 910 m and peaks of over 2,100 m (Raj, 2009).

According to Raj (2009), there are five broad topographic units that can be distinguished based on differences in mean elevations: (1) Low lying (<15 m above sea level); (2) Rolling (16 – 30 m); (3) Undulating (31 – 75 m); (4) Hilly (76 – 300 m); and (5) Mountainous (>301 m). Meanwhile, Tanot Unjah et.al. (2001) divided the landscape in the state of Kelantan into four types, they are: (1) Mountainous areas; (2) Hilly areas; (3) Plain areas; and (4) Coastal areas. The Lojing Highlands itself is dominated by the topography of mountainous areas (Figure 4). Mountains alternating with valleys dominate the topography of the study area. The highest point of the study area is nearly 2,000 m above mean sea level which is in the southeast of the area, near the Kelantan – Pahang border, meanwhile the lowest one is 600 m above mean sea level in the north. Some features in the mountainous area are mountain ridges and mountain valleys (Figure 5).

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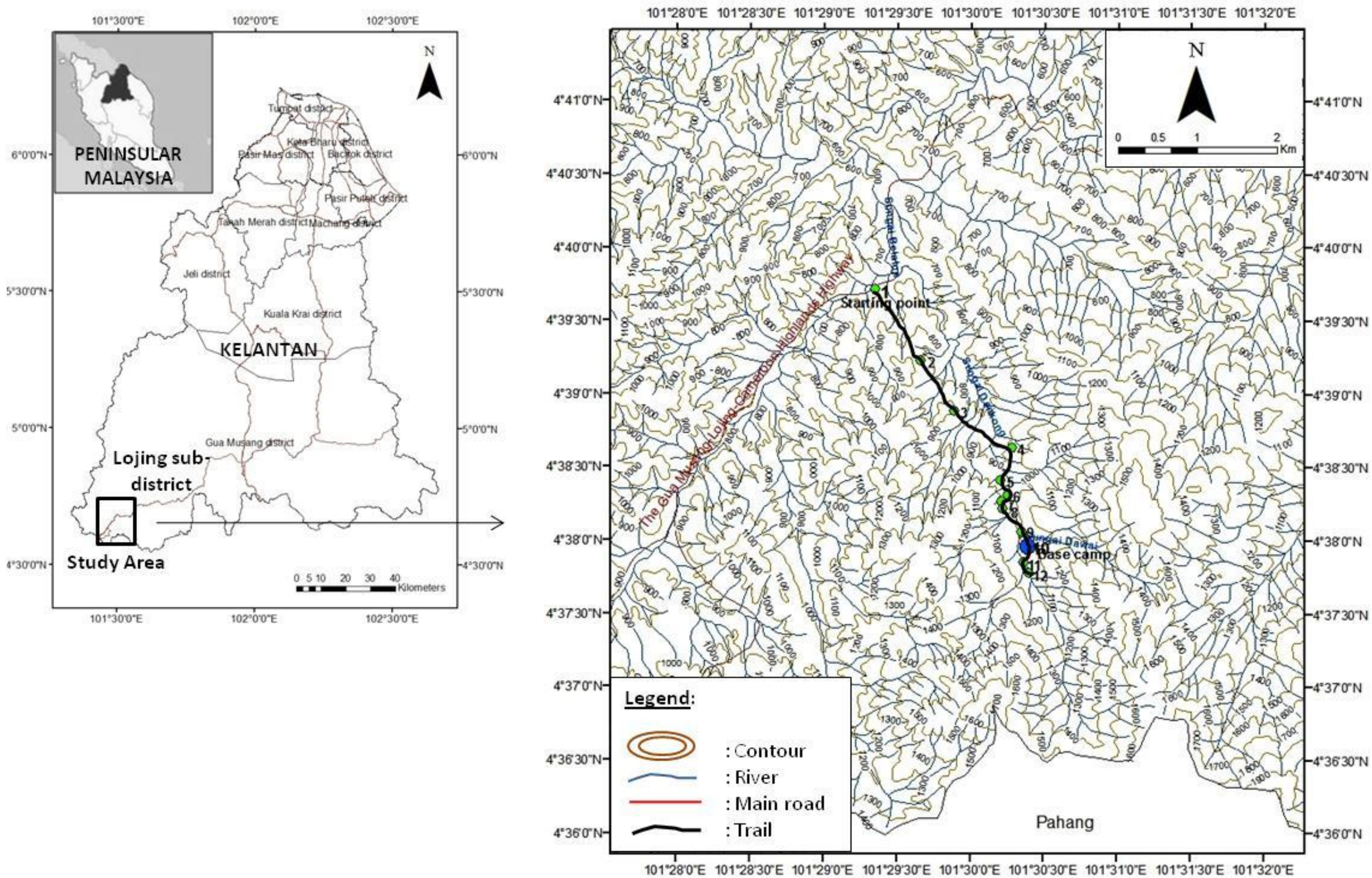

Figure 1: Maps of the study area: (a) Location map; and (b) Topographic map (base map)

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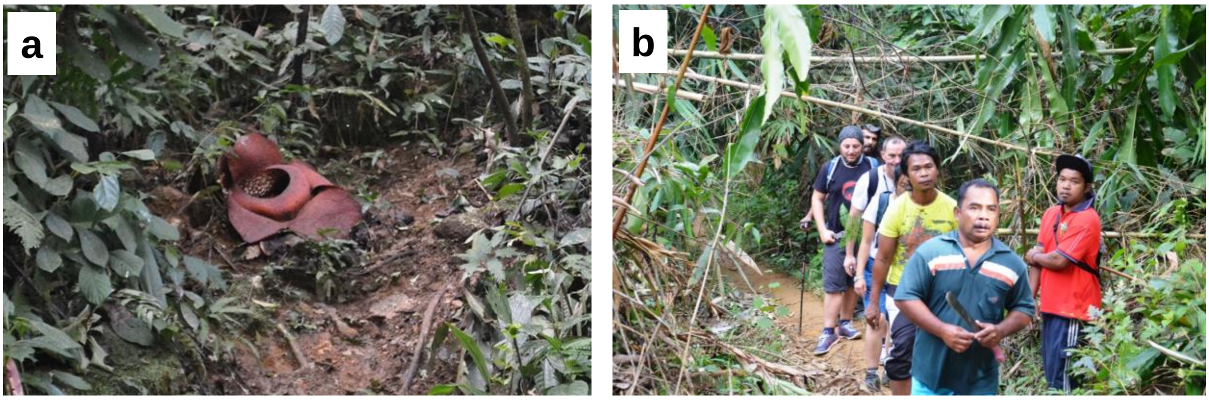

Figure 2: *Rafflesia kerri*, the icon and the main tourism attraction of Lojing Highlands. (a) A *Rafflesia* in the opening phase; (b) Some local tour guides and international tourists visit the area for observing the flower.

The drainage pattern of the area is subdendritic and angulate (Figure 6). Subdendritic pattern (a modified pattern of dendritic type) is presumably controlled by secondary regional controls, such as structural. Meanwhile, angulate (a modified of rectangular) is characterized by numerous acute-angle bends and barbed tributaries which are controlled by joints and/or faults (Howard, 1967; Fryirs and Brierley, 2013). From these drainage patterns, it can be interpreted that generally this area has been affected by the structural controls such as joints and/or faults. Certain lineament directions can be seen in the study area. For instance, the study area is mostly along the Sungai Denkong that is at least 7 km long with a bearing around N1500E. The main factor controlling the drainage basin of Sungai Dengkong is the approximately NNW–SSE-trending mountain range. This river follows almost parallel to the mountain range. Generally, tributaries of this river flow relatively to the east or the west (Dony Adriansyah et.al., 2014).

Highland areas in Peninsular Malaysia are formed by a long erosional history through successive uplifts during Cenozoic. This morphology is largely controlled by rock type and structure. The topography is characterized by steep valley walls, numerous waterfalls and rapids, and small remnant upland plateau now providing hill resort like the Cameron Highlands. These features indicate a youthful stage of erosion (Tjia, 1973). In this stage, after uplift, a youthful landscape is characterised by incising V-shaped (steep-sided) valleys because of the rapid deepening of the channels. The rivers flow along an uneven surface and confined valleys. There is intensive and rapid vertical erosion and the gradients are steep (Figure 7).

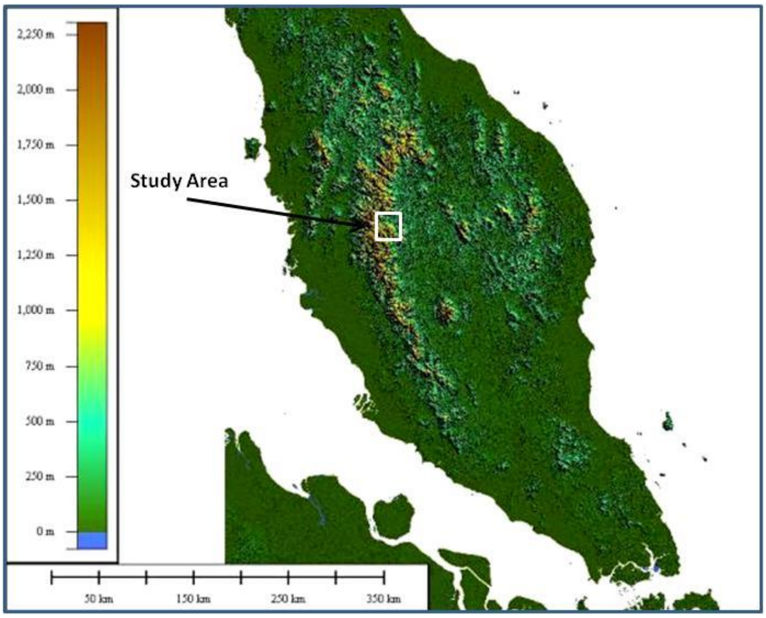

Figure 3: Digital Elevation Model (DEM) Map of Peninsular Malaysia shows the physiography of the Peninsular. The study area (the area in the white box) is located in the foot of the Main Range (or the Titiwangsa Range).

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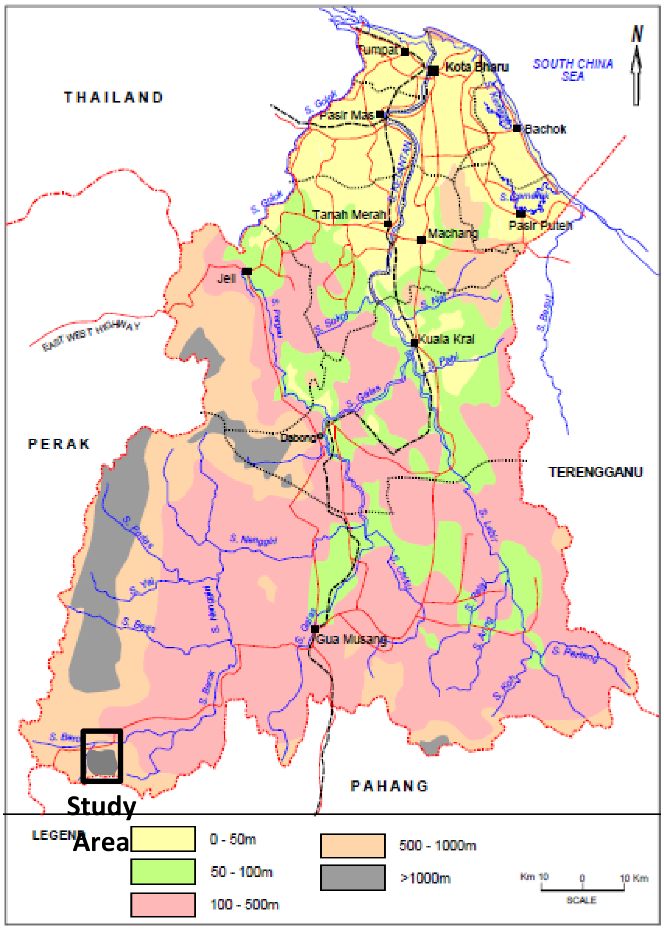

Figure 4: General topography of Kelantan (after Dept. of Minerals and Geoscience Malaysia, 2003). The Lojing Highlands is dominated by the topography of mountainous areas.

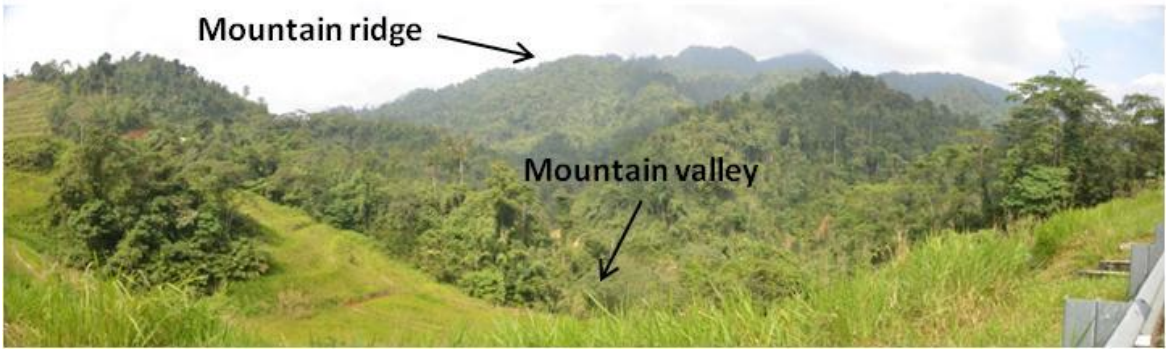

Figure 5: Topography of the study area is dominated among others by mountain ridges and mountain valleys (Dony Adriansyah *et. al.*, 2014).

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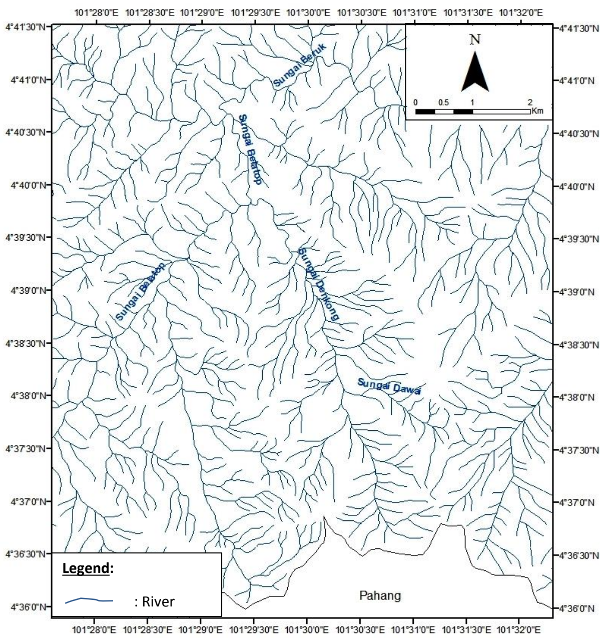

Figure 6: Drainage pattern of the study area is subdendritic and angulate (Dony Adriansyah et. al., 2014).

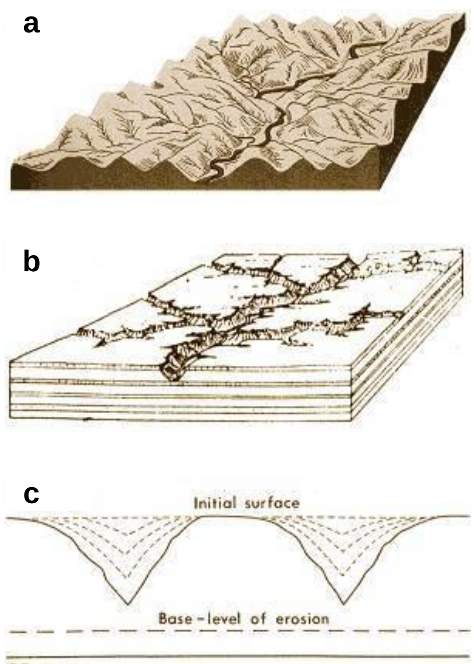

Figure 7: Model of young stage of Davisian cycle of landscape erosion in the study area (after the Association of Polish Geomorphologists, 2009). Rivers in this stage have V-shaped (steep-sided) and confined valleys.

Some fluvial landforms or geomorphic units occur in the study area, such as waterfalls, cascades, rapids, runs, pools, potholes, lateral bars, and point bars (Dony Adriansyah et. al., 2014; Figure 8). Waterfalls are usually caused by the rivers encountering some locally and highly resistant rocks whilst deepening their valleys. Waterfalls are characterised by falling water flow over bedrock that have a near-vertical drop greater than 1 m. Waterfalls vary considerably in height, form and volume of water. Some of them are small and narrow waterfall and some others are large, even exceptionally large falls occur in some parts in the mountainous areas. Cascades occur on steep slopes and comprise longitudinally and laterally disorganised bed materials, typically cobbles and boulders. A stair-like morphology may develop in settings where the materials are better organised. Rapids are formed by arrangements of boulders in irregular transverse ribs that partially or fully span the channel in bedrock-confined settings during high energy events. In addition, rapids are also caused in many cases by the recession of the waterfall, whilst others occur where streams are eroding rocks of unequal hardness. Runs (or glides) are generally uniform and relatively featureless bed, comprising bedrock or coarse clasts (cobble or gravel). Runs are typically generated under plane-bed conditions with smooth flow. Pools are deeper and confined areas with tranquil flow within high energy settings, usually associated with irregular spaced bedrock outcrops and woods. Pools may accumulate finer grained materials and they are flushed and possibly scoured. Potholes are spherical/circular features sculpted in bedrock by hydraulic and abrasive action of water (erosion during turbulent flow). The effectiveness of this process is determined by the volume and hardness of particles that are trapped in the potholes. Abrasion is induced by these particles, which deepen and widen the potholes. Lateral bars (alternate or side bars) are elongate features attached to banks along relatively straight channels. These bars form by lateral (or oblique) accretion processes, with some suspended-load materials atop (typically fining-upward depositional sequence). Point bars typically have an arcute shape that reflects the radius of curvature of the bend within which they form. These bars develop along the convex banks of meander bends and follow the alignment of the bend. The bar surface is typically inclined towards the channel (Raj, 2009; Fryirs and Brierley, 2013).

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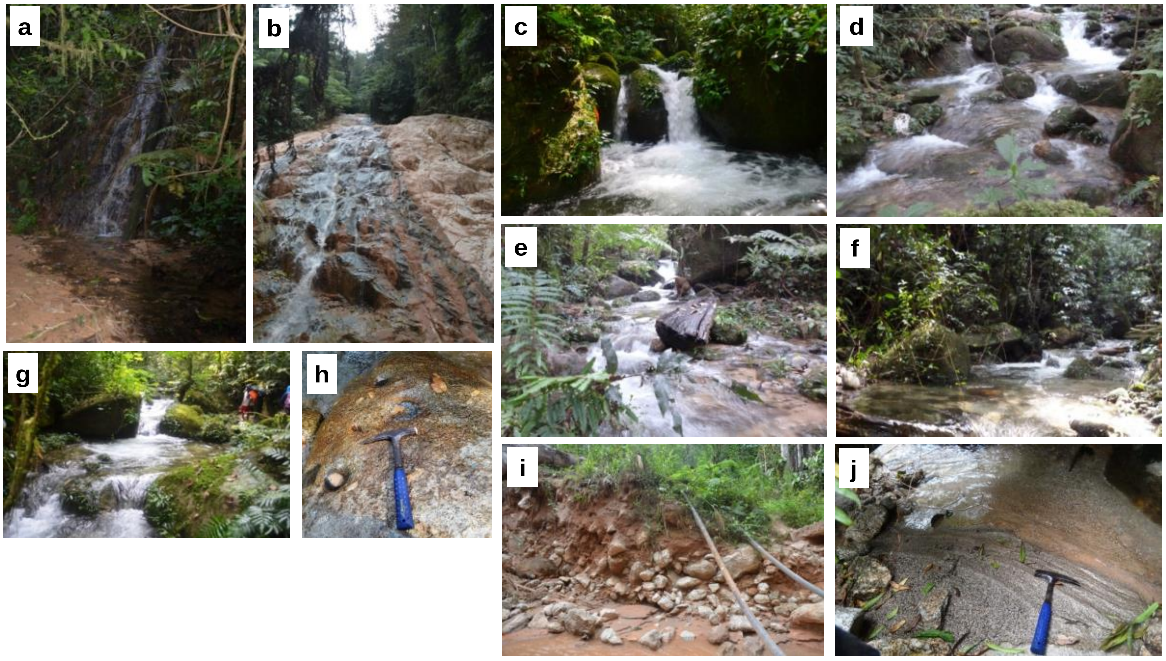

Figure 8: Some fluvial landforms occur in the study area, such as (a), (b), (c) Waterfalls with different sizes, (d) Cascade, (e) Rapids, (f) Run, (g) Pool, (h) Potholes, only a few and small size, (i) Lateral bar, and (j) Point bar (Dony Adriansyah *et. al.*, 2014).

3.2. Lithology of Study Area

Che Abdul Rahman and Kamal Roslan Mohamed (2001) explained that the state of Kelantan consists of various rocks, including igneous, sedimentary and metamorphic rocks. The rocks in Kelantan are distributed in a north – south trend. For igneous rocks in Kelantan, they are distributed in the west and east borders of the state (the Main Range granite and the Boundary Range granite) and also occur in the centre of the state (Figure 9).

The geology of Kelantan can be broadly classified into four rock types, they are: (1) Unconsolidated sediment; (2) Extrusive rocks (volcanic rocks); (3) Sedimentary/ metasedimentary rocks; and (4) Granitic rocks. For granitic rocks in Kelantan, they can be divided into two main bodies: the granite bodies within the Main Range and the Boundary Range. The Main Range granite is generally of a Late Triassic age, between 200 and 250 millions years ago (Dept. of Minerals and Geoscience Malaysia, 2003).

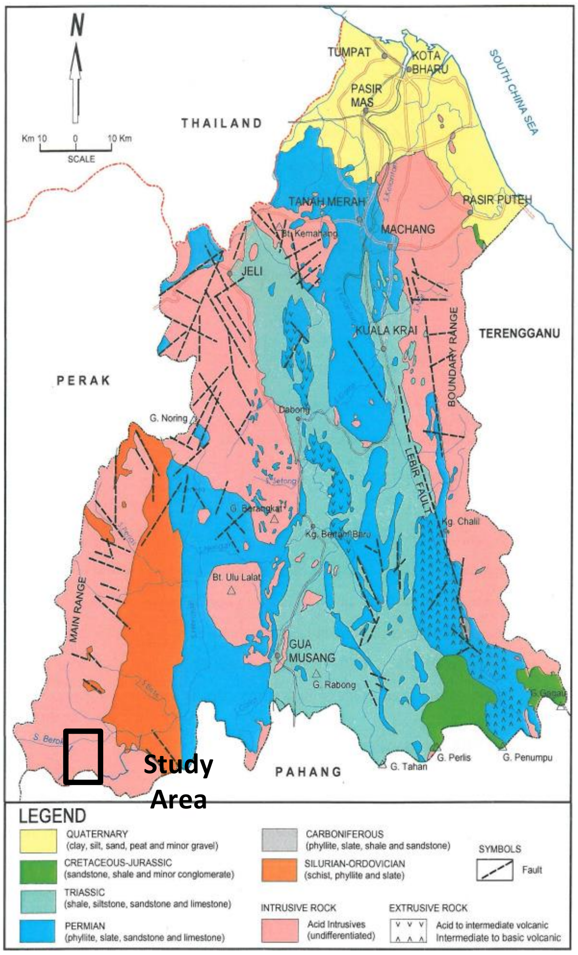

Figure 9: General geology of Kelantan (after Dept. of Minerals and Geoscience Malaysia, 2003).

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As mentioned before, the study area is situated in Lojing Highlands, which is a part of the Main Range. This range consists mostly of granite with several enclaves of metasedimentary rocks (Raj, 2009). The Main Range granite in Kelantan located roughly in the west of the state stretching along western Kelantan up to the state boundary of Perak and Pahang, and international boundary of Thailand. According to Azman Ghani (2009), the main rock type of the Main Range Granite Province is a coarse to very coarse grained megacrystic biotite granite. Large K-feldspar phenocrysts up to 7 cm long are common and often show a distinctly megacrystic appearance in hand specimen.

Granite outcrops in the study area can be found in large and very large granite bodies and boulders mainly along the rivers. There is no sedimentary and metamorphic rocks found in the study area. Detailed descriptions of rocks in the study area were conducted to some outcrops and hand specimens. Some fresh outcrops in the study area show that the granitic rocks are mostly granite porphyry or porphyritic granite. The rock is light gray, usually weathered to dark gray, and typically coarsed-grained, containing large phenocrysts of white potassium feldspar up to 7 – 8 cm long. Coarsed-grained groundmass consists of plagioclase, quartz, and biotite. Some granites contain xenoliths (size: > 10 cm) (Figure 10).

Other than granitic rocks, the study area is also covered by the Quaternary deposits which are alluvium deposits or unconsolidated sediments. The sediments overlie the granitic bedrock and were deposited mainly along the river. The sediments have been transported and deposited by the river flow to form some deposits such as the river banks and sand bars (Figure 11).

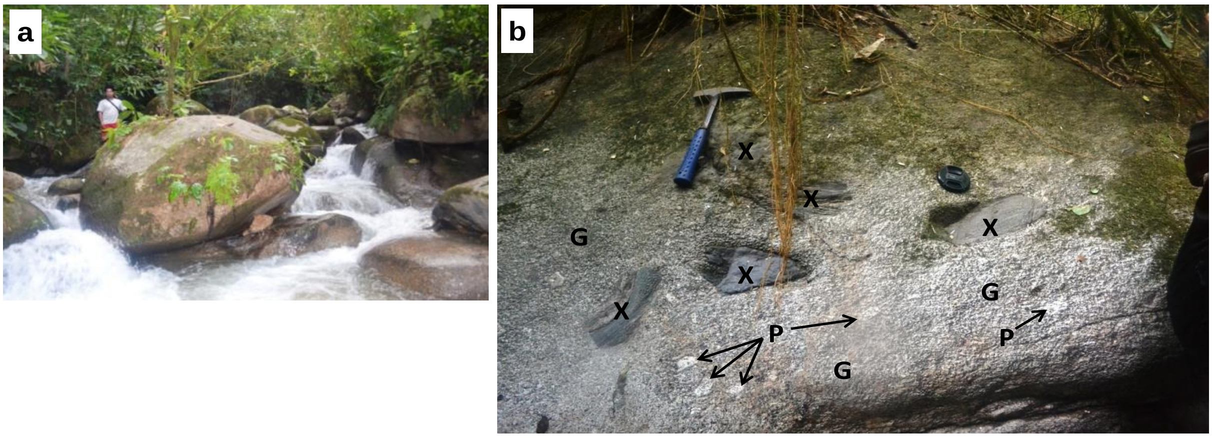

Figure 10: Some granitic outcrops in the study area. (a). Granitic boulders in Sungai Denkong; (b) One of fresh granite outcrops shows the components of the rocks, they are phenocrysts (indicated by **P**), groundmass (**G**) and xenoliths (**X**).

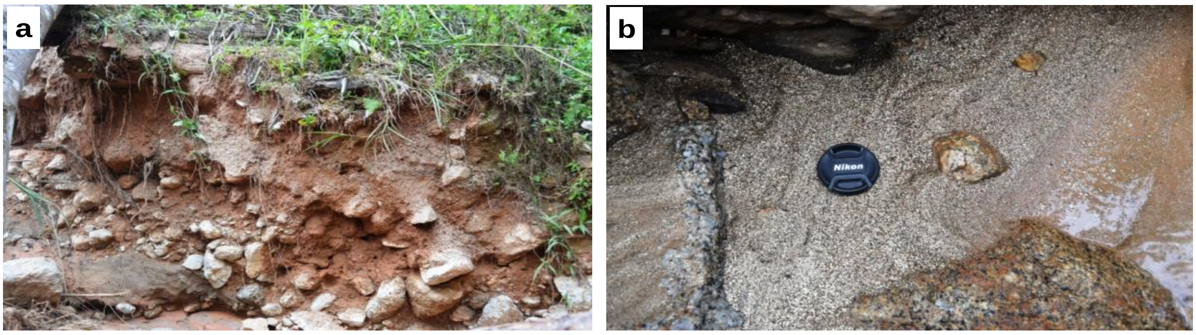

Figure 11: Quaternary deposits in the study area. (a) Lateral bar in the river bank of Sungai Bajis in the study area consists of clay- to gravel-sized unconsolidated sediment with fining-upward sequence. (b) A fine-grained point bar consists mostly of pyritic sands.

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3.3. Structural Features

The main force acting on the land mass of Peninsular Malaysia was compressional and its effects are principally faulting and folding in the scale of regional and local. Localised structures include folding, faulting, and jointing in the sedimentary rocks, and faulting and jointing in the granitic rocks. The dominant structural grain is along a N – S to NW – SE direction resulting from past orogenies (Dept. of Minerals and Geoscience Malaysia, 2003).

Figure 12: Joints cut the granite body in the study area resulting roughly angular fragments (“brecciation”)

Geological structures that are commonly found in the study area are joints and brecciation. Joints are fractures in rocks, with no displacement has occurred. Joints can be systematic or non-systematic, and usually occur as fractures which intersect at angles ranging from 450 to 900. In the study area, joints divide the rock body into large, roughly angular blocks, which is called as brecciation (Figure 12). According to Hamblin (1994), joints resulted from strain that occurs when the rocks are uplifted, tilted, folded, or fractured by tectonic forces. The close-spaced fractures would weaken the rock mass and make it more susceptible to weathering and erosion.

For the sedimentary structure in the study area, some parts of modern sediments in the rivers exhibit ripple mark structures (Figure 13). This structure is a small wave structure (with nearly parallel ridges and troughs) that is formed on a surface of sand and mud by moving water over it (Hamblin, 1994; Thomson & Turk, 2007). In the study area, the river currents have formed interesting patterns of small ripple marks in flat sandy bed by ongoing geological process. Based on the observation, there are two types of ripple marks can be found in the study area, they are symmetric and asymmetric ripple marks. The geometry of ripple marks depends on the dominant current direction. The symmetric ripples are created by a two-way current and have symmetrical profile. The asymmetric ripples form in response to water currents flowing in one direction and have asymmetric profile. In asymmetric ripples, one side of the ripple has a shallow, gentle, and longer slope, while the other is steep and abrupt. The longer side always faces the upstream direction.

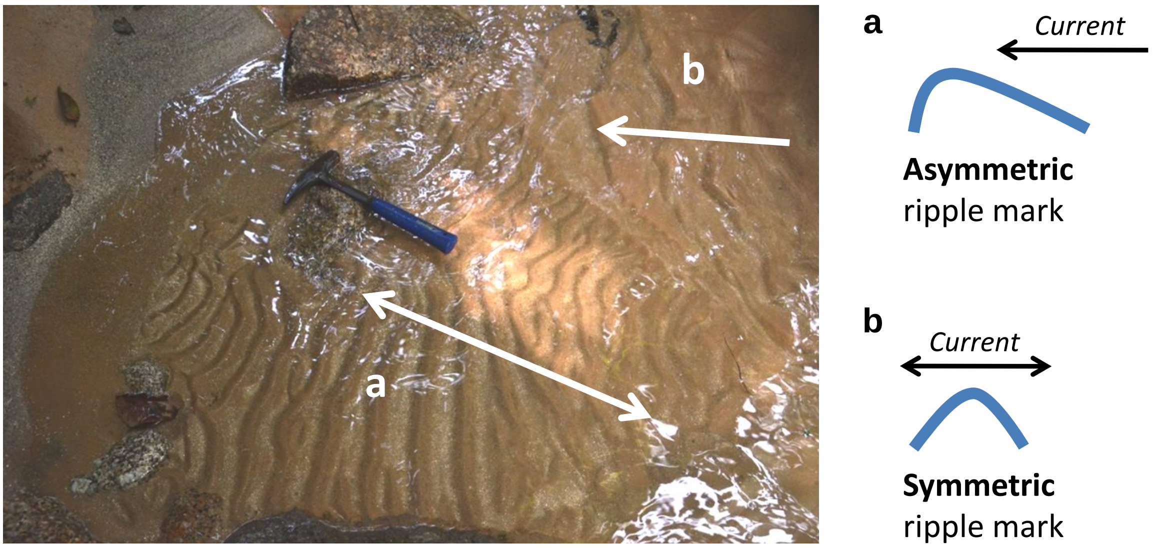

Figure 13: Two types of ripple marks produced on a streambed in the study area indicating the current action of water: (a) Asymmetric ripple mark, and (b) Symmetric ripple mark. The arrows show the current directions.

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3.4. Geohazard Potentials

The deforestation in the study area has significant effects on its environment. One of the effects is the potential geological hazard i.e. landslides (Dony Adriansyah et.al., 2014). According to Bolt et.al. (1975), landslides occur on slopes in a variety of geological materials and develop through a variety of mechanisms and causes. Some parameters are used to classify the landslides, such as material, velocity (rate), scale of the event, displacement (distance), as well as mechanism of movement. The most obvious difference between various kinds of landslide is the nature of participating materials. Some slides are entirely composed of rock material, others of soil only, and a few are mixed materials (such as rock and soil). For the velocity of the event, in general terms, rapid landslides occur in seconds to minutes; intermediate rates of movement may be scaled in minutes to hours; and slow landslides develop and move in periods ranging from days to years. The scale of the event and displacement can be measured in the field using units such as meters and kilometers. There are several types of landslides which imply the mechanisms of movement, such as fall, slide, and flow.

Table 1: Classification of some landslides in the study area (Dony Adriansyah *et. al.*, 2014)

No.	Code of Landslide	Coordinate (N & E)	Material	Scale (height x width)	Displacement	Mechanism
1	LS-1 (Figure 14.A)	04^0 39' 13.6" 101^0 29' 39.5"	Soil	5 m x 5 m	A few meters	Slide
2	LS-2 (Figure 14.B)	04^0 38' 13.1" 101^0 30' 13.0"	Soil	7 m x 5 m	A few meters	Slide
3	LS-3 (Figure 14.C)	04^0 38' 53.1" 101^0 29' 53.2"	Soil + Rock	3 m x 3 m	A few meters	Slide + Rockfall
4	LS-4 (Figure 14.D)	04^0 38' 18.5" 101^0 30' 15.6"	Soil + Rock	4 m x 3 m	A few meters	Slide + Rockfall

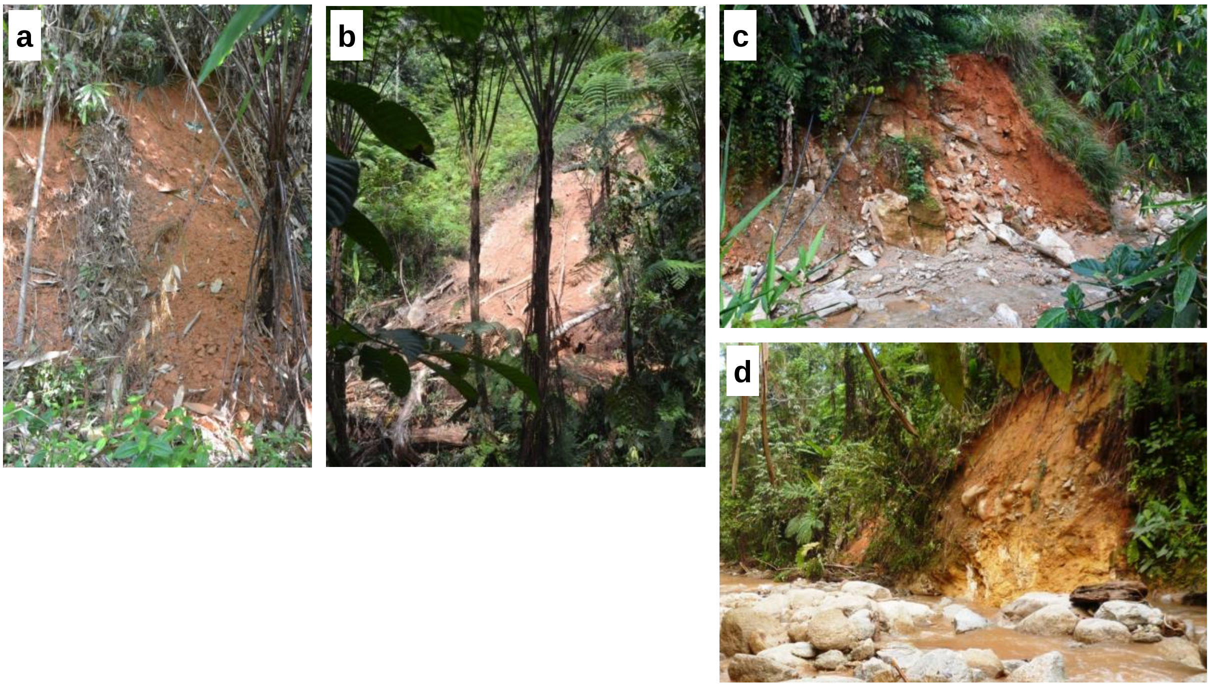

Figure 14: Some landslides in the study area: (a) and (b) Landslides composed of soil only; (c) and (d) Landslides composed of soil and rock (Dony Adriansyah *et. al.*, 2014).

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According to Dony Adriansyah et.al. (2014), there are several landslides occur in the study area recently (Table 1, Figure 14). Although they are small landslides (only a few meters in dimension and displacement), but they still can become a threat and an inconvenience to the area and visitors. Some landslides in the study area are entirely composed of soil only and some others are mixtures of rock and soil. The velocity of the event is difficult to decide since the observation has only been conducted after the events. These landslides occurred in unstable hill slopes in the study area. The type of movement depends on the characters of the material taking part in the movement and the topography (plane or surface of movement). Almost all movements are slides, where we still can observe the sliding surfaces and the sliding materials (mostly soil). For brittle rocks in the steep slopes, the consequence of rock failure will be a fall rather than a slide. So, the mass of rocks, even if they are part of the slide, may fall freely under gravity.

4. Conclusions

Although this area has no special or unique geological features, geological review of this area is important to be performed to give detailed and updated geological inputs in terms of geomorphology, lithology, structural features, and geohazard potentials. The study area is famous for its Rafflesia and has become the main attraction in Lojing Highlands. This area is also attractive with its mountainous area and some fluvial features, such as waterfalls, cascades, rapids, pools, potholes, and so on. It is monotonously composed of granitic rocks, mostly granite porphyry, and covered by Quaternary deposits. Meanwhile, the geological structure that is commonly found in the study area is joints. The recently active deforestation in the area has given some impacts on the environment, such as landslides. It is suggested that this area should be conserved and developed properly. This study also recommends that this area should be supported as a sustainable nature-based tourism site in Lojing Highlands.

Acknowledgments

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Appendix A

Details of Observation Points and Locations in the Study Area

Observation Point	Coordinates (N & E)	Location and Feature	Elevation (m)
1	04^0 39’ 43.4” 101^0 29’ 20.8”	Starting point of the *Rafflesia* Trails	688
2	04^0 39’ 13.6” 101^0 29’ 39.5”	A small landslide	847
3	04^0 38’ 53.1” 101^0 29’ 53.2”	A small landslide (slide + rockfall)	889
4	04^0 38’ 37.7” 101^0 30’ 16.8”	A small waterfall (~10 m)	951
5	04^0 38’ 21.8” 101^0 30’ 10.1”	A *Rafflesia kerrii* is blooming	965
6	04^0 38’ 18.5” 101^0 30’ 15.6”	Meeting point between S. Denkong and S. Bajis. A small landslide (slide + rockfall)	997
7	04^0 38’ 15.9” 101^0 30’ 12.4”	A large waterfall (part of S. Bajis, a tributary of S.Denkong)	992
8	04^0 38’ 13.1” 101^0 30’ 13.0”	A small landslide	1005
9	04^0 38’ 03.5” 101^0 30’ 20.6”	Meeting point between S. Denkong and S. Dawai	941
10	04^0 37’ 57.3” 101^0 30’ 23.5”	Base camp	1040
11	04^0 37’ 50.4” 101^0 30’ 21.4”	S. Denkong (towards upstream)	1047
12	04^0 37’ 46.2” 101^0 30’ 23.9”	A small waterfall and cascade (part of S. Denkong)	1050

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