



Mineralogical Analysis of Plutonic and Volcanic Rocks at Selected Slope Sections of the Kuala Lumpur-Karak Highway



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Abstract

The Kuala Lumpur-Karak Highway (KL-KH) is the main highway connecting Kuala Lumpur to the East Coast states in Peninsular Malaysia. It traverses three (3) different formations: the Kuala Lumpur Granite, Genting Sempah complex, and Bentong Raub Suture zone. Each formation has a distinctive rock mineral composition and microstructure that determines the strength and kinematics of rock masses. This study performed X-ray Diffraction (XRD) and Scanning Electron Microscopy (SEM) to analyze the mineralogy of plutonic and volcanic rocks from the KL-KH. The plutonic sample at KM29 (GKM29) is an igneous rock composed of quartz, muscovite, and albite, and the volcanic sample at KM93 (LKM93) is rhyolite comprising quartz, albite, muscovite, and biotite. Even though the mineral content of both samples was similar, they had different textures and percentages of quartz, feldspar and carbon content. The different texture and percentage of minerals contribute to the stability of the slope. It can be used as an early indicator for slope study.

Keywords:

Petrography; Granite; Rhyolite; X-Ray Diffraction; SEM

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INTRODUCTION (R: 31, G: 78, B: 121)

Peninsular Malaysia is segmented into three primary longitudinal belts: Western, Central, and Eastern. These belts are distinguished by their stratigraphy, geological history, and magmatic characteristics [1]. The long history of tectonic and volcanic activities influenced the formation of the different rock types consisting of distinct minerals and micro textures that determine their strength and kinematics. The Kuala Lumpur-Karak Highway (KL-KH) spans across these primary belts. Table 1 presents the objective of previous studies on the KL-KH that investigated the history of geological formations and conducted slope stability analysis. However, very few studies

focused on conducting mineral and petrography analysis of the plutonic and volcanic rock of the KL-KH.

Plutonic and volcanic rocks are igneous rocks classified according to locations, mode of formation and mineralogy. Plutonic or intrusive rocks (i.e. granite) crystallized, solidified and cooled below the earth's surface and are composed primarily of quartz, feldspar, biotite, and muscovite [2]. Volcanic rocks are extrusive rocks formed from rapid lava solidification above the earth's surface (i.e. rhyolite). According to [3], both rocks can be porphyritic and have similar phenocryst assemblage. Despite their identical

SiO₂ content, they have distinct textures and mineralogy.

The volcanic rock phenocryst is surrounded primarily by a fine-grained matrix or groundmass that is not easily distinguishable to the naked eye [4][5]. Even though local researchers have studied their petrography and geochemistry [1][3] there is still a dearth of comprehensive comparative studies of these rock types at the KL-KH.

This study made a detailed analysis of the mineralogy of plutonic and volcanic rocks from

selected outcrops of the slope sections at KM29 and KM93 of KL-KH to provide valuable insight into the mineralogy of the rock material. The data is beneficial in correlating mineral assemblage, rock strength, and how they influence rock slope instability, thus providing an understanding of potential rock slope failures in the study area crucial in developing effective mitigation measures.

Table 1. Previous studies associated with KL-KH

No	Year	Research Scope and Objective			References
		Historical of Geological Formation	Petrology & Mineralogy Analysis	Others	
1	1983	/			[6]
2	1994			Kinematic analysis	[7]
3	2000	/			[8]
4	2005		/		[1]
5	2009			Microcrack pattern	[9]
6	2010			Slope stability study using GIS	[10]
7	2012	/			[11]
8	2015	/			[12]
9	2019			Slope stability using kinematic and LEM	[13]
10	2021			Soil shear strength	[14]
11	2022			Rock mass quantification	[15]
12	2023		/		[16]

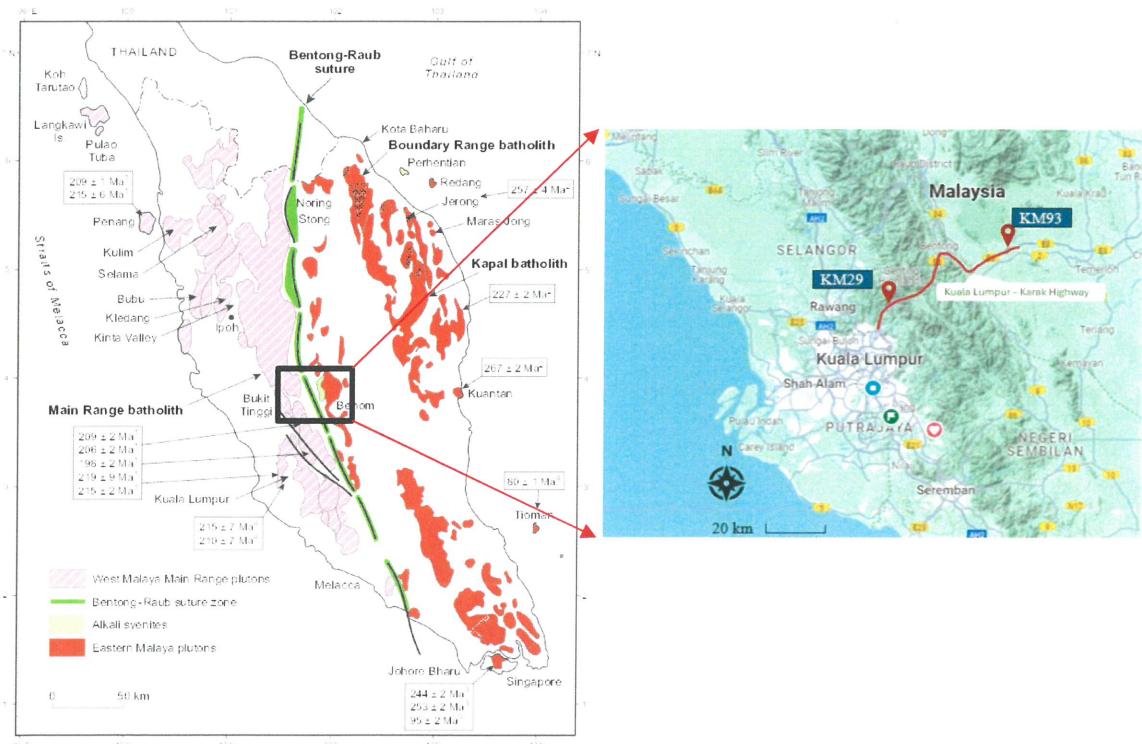


Figure 1. Division of granites in Peninsular Malaysia and location of study area. Modified from [17]

GEOLOGICAL AND STRATIGRAPHICAL SETTINGS

The Kuala Lumpur-Karak Highway is the main highway connecting Kuala Lumpur to the East Coast states in Peninsular Malaysia, spanning from Gombak, Selangor, to Lanchang, Pahang. It traverses flatland and mountainous terrain across three geological formations: the Kuala Lumpur Granite, Genting Sempah complex, and Bentong Raub Suture zone. These formations lie within the Main Range of Peninsular Malaysia, also known as Western Belt Granites, as shown in Figure 1.

The Main Range Granite formed in the Permian to Triassic age, and each formation in the area has a distinctive granite unit. Unit 1 consists of megacrystic biotite granite, Unit 2 comprises megacrystic muscovite-biotite granite, Unit 4 is predominantly microgranite, aplite, and pegmatite, and Unit 3 is equigranularity tourmaline-muscovite granite [17].

METHOD

Rock Sample Collection and Field Observation

The fresh rock samples were collected from two exposed outcrops at KM29 and KM93 of the KL-KH between longitude and latitude $3^{\circ}30'38.8''\text{N} / 102^{\circ}07'36.0''\text{E}$ and $3^{\circ}18'54.8''\text{N} / 101^{\circ}44'13.6''\text{E}$, respectively. The rock samples were obtained using a geological hammer. The sample extracted at KM29 was designated GKM29, and that from KM93 was LKM93 (see Figure 2). The field investigation and observations determined the characteristics of rock materials. GKM29 has coarse to medium grain texture, with yellowish to whitish grey. LKM93 is fine-grained and yellowish to whitish grey. The similar yellowish to whitish-grey color of both samples suggests an identical mineral composition and any color variations could be due to the differences in alteration or weathering processes. The weathering grades at both slopes are classified as grade III and IV, based on their appearances. Figure 3 shows the jaw crusher and tungsten carbide mill machine employed in preparing the solid and powdered samples.

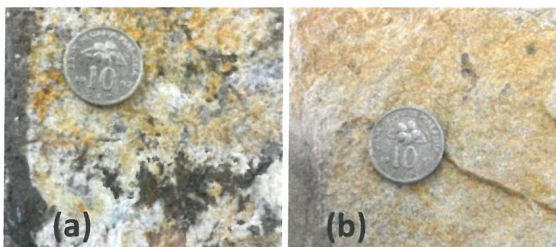


Figure 2. Rock sample (a) GKM29 - granite (b) LKM93 – rhyolite



Figure 3. Rock sample preparation using (a) jaw crusher (b) tungsten carbide machine.

X-Ray Diffraction (XRD) Sample Preparation

This study quantified the mineral composition of the rock samples using the Rigaku ZSX Primus IV machine to conduct the XRD and calculated the diffraction angle beamed by the X-ray transmission. The rock sample was micronized into a homogenous size and compressed into a powder pellet, as shown in Figure 4.

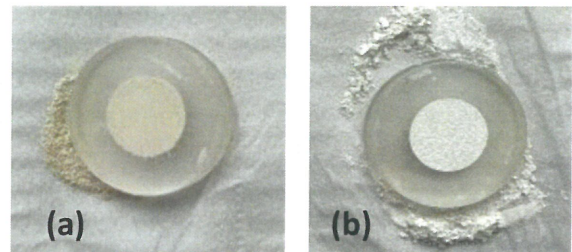


Figure 4. Powdered sample for XRD analysis (a) sample GKM29 (b) sample LKM93

Scanning Electron Microscope (SEM) Preparation

Figure 5 shows the rock sample on the SEM holder. The Carl Zeiss Gemini SEM 500 Model high-resolution scanning electron microscope equipped with a field emission gun and an Oxford Instrument energy-dispersive X-ray spectroscopy (EDS) was used to analyze mineral composition. The spectra were processed using the Smart SEM 5.0 software at 500 times magnification.

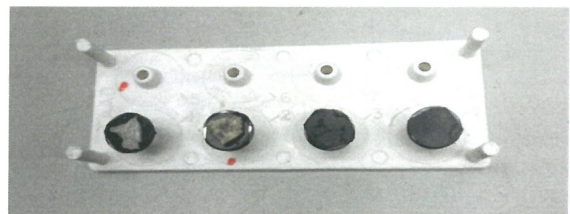


Figure 5. Sample mounts (both chip and powder) on holder.

RESULTS AND DISCUSSIONS

XRD Analysis

The mineral phase identification based on the XRD patterns confirmed the presence of the common minerals indicative of felsic igneous rock (rich in Si, Al, Na, and K). The XRD results in Figure 6 show that varying concentrations of quartz, feldspars, and micas are the common minerals in granite and rhyolite, congruent with the results reported by [18][19]. Albite from the feldspar group was dominant in the GKM29 and LKM93 samples, with amount of 46.9% and 57.3%, respectively. Quartz mineral in GKM29 sample accounted for more than 40% compared to LKM93, 31.9%. Quartz is the most resistant among the commonly occurring minerals [20][21]. The abundant quartz in the GKM29 enhanced its mechanical properties, making it resistant to weathering [22][23]. Muscovite was present in a small amount of 11% in the GKM29 sample and 7.9% in LKM93. Biotite is present in LKM93 in trace amounts (3%). Table 2 presents a comparison of the mineral contents of both samples.

SEM Analysis

The EDS mapping image confirmed the elements in the micro-scale mineral phase, as shown in Figure 7. Both samples show varying concentrations of similar trace elements, namely Si, O, and C. The results in Table 3 are in weight percentage. The high proportion of Si and O (forming the silicate mineral (SiO_2)) in both samples are the characteristics of volcanic and plutonic rocks. The Si was abundance in GKM29 compared to LKM93, congruent with XRD analysis.

One of the elements present in high concentrations in both samples is carbon. The LKM93 contained 31.91% carbon, and the GKM29 contained 16.3%. The higher carbon content in LKM93 is due primarily to the higher volatile content of the rhyolitic magma and rapid cooling that traps higher concentrations of the volatiles within the rock [24]. The slower cooling of granitic magma allows more time for carbon removal through mineral formation and segregation [25].

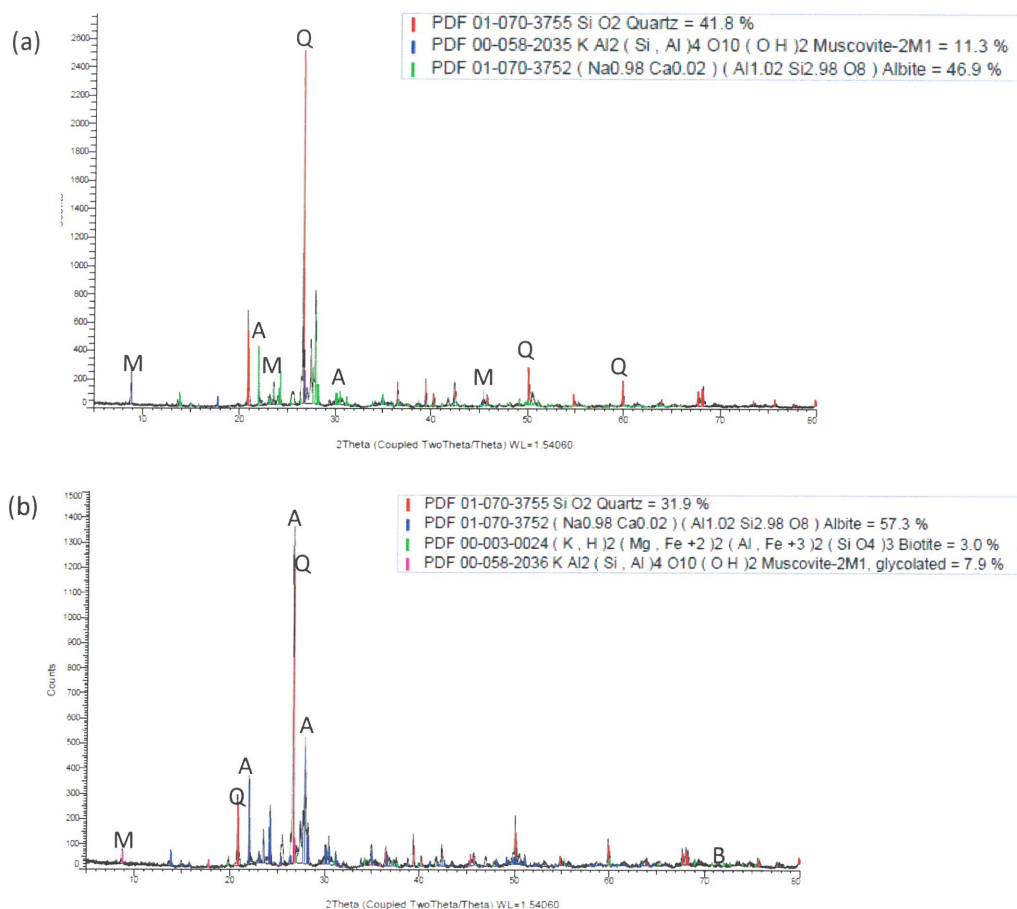


Figure 6. Powder X-ray diffraction patterns of samples (a) GKM29 (b) LKM93 Abbreviations: Q, quartz; M, muscovite; A, albite; B, biotite

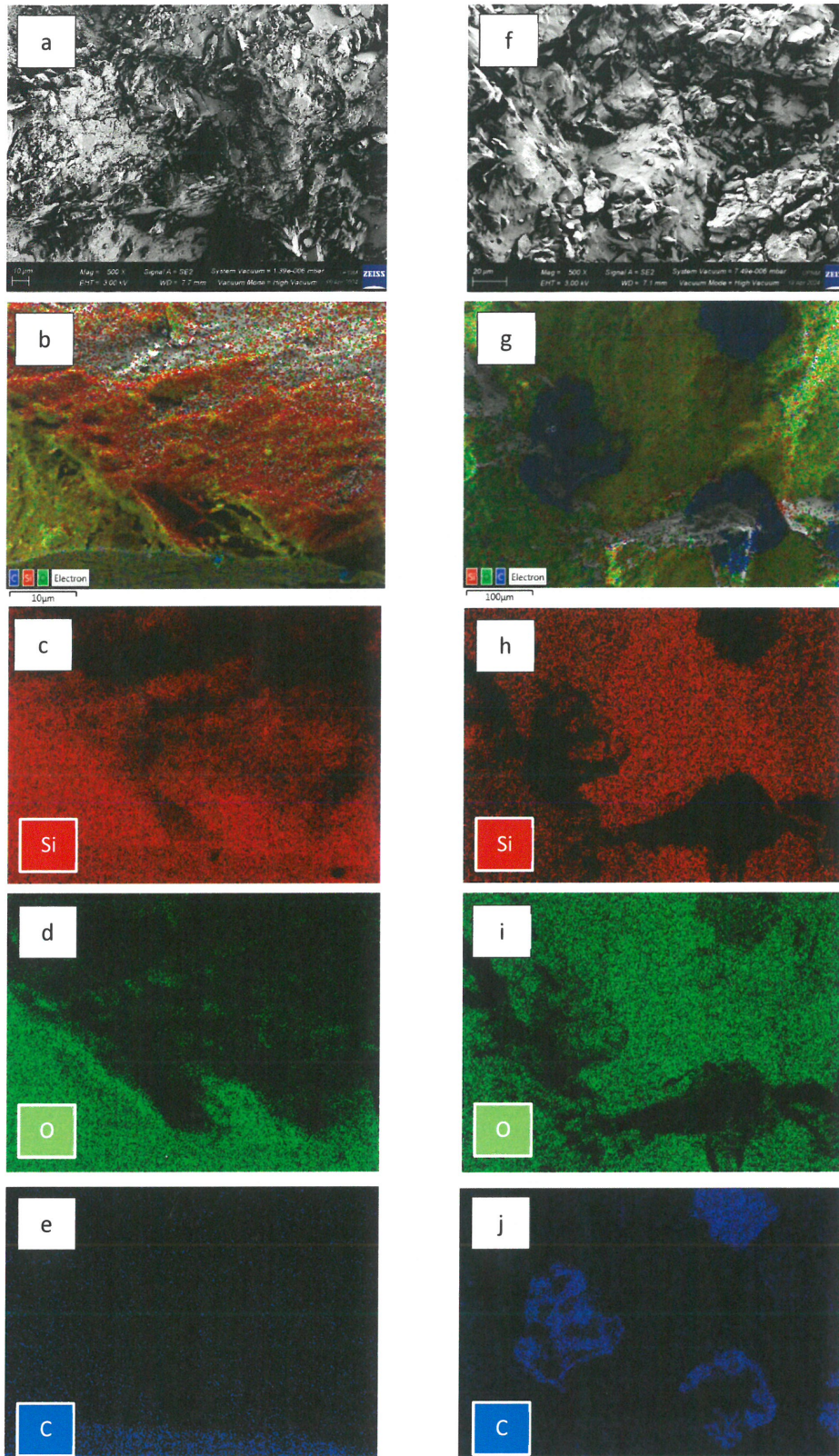


Figure 7. SEM and SEM-EDS analysis. Maps of layered, Si K α 1, O K α 1, C K α 1 (a-e) GKM29 (f-j) LKM93

Table 2. XRD contrast between granite and rhyolite

Minerals	GKM29 (%)	LKM93 (%)
Albite (Feldspar)	46.9	57.3
Quartz	41.8	31.9
Muscovite (Mica)	11.3	7.9
Biotite	0	3

Table 3. EDS analysis of element presence in sample

Element	GKM29 (%)	LKM93 (%)
Si	36.81	13.98
O	46.89	54.11
C	16.3	31.91

CONCLUSION

The GKM29 plutonic (granite) sample had a coarse to medium texture, and LKM93 had a fine-grained texture. The GKM29 comprised quartz, muscovite, and albite, while LKM93 consisted of quartz, albite, muscovite, and biotite. Feldspar was dominant compared to quartz in both samples. Quartz mineral in GKM29 sample accounted for more than 40% compared to LKM93, 31.9%. Even though the mineral content of both samples was similar, they had different textures and percentages of quartz, feldspar and carbon content. The different texture and percentage of minerals contribute to the stability of the slope. It can be used as an early indicator for slope study.

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