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Exploring Silicate-Rich Minerals in Mangguliling Nature Park: A Microscopy and Diffraction-Based Study

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Abstract

This study aims to identify and classify the mineral content of rock samples collected from the Mangguliling Nature Park, Segeri District, Pangkajene and Islands Regency. Various characterization techniques, including Scanning Electron Microscopy coupled with Energy Dispersive Spectroscopy (SEM-EDS), X-Ray Diffraction (XRD), and Optical Microscopy, were applied to determine the elemental composition, crystalline structure, and surface morphology of the samples. The SEM-EDS analysis revealed that the dominant elements in Melati 01 were oxygen (O), carbon (C), magnesium (Mg), silicon (Si), and iron (Fe), while in Melati 02 the primary elements included oxygen (O), silicon (Si), carbon (C), and aluminum (Al). XRD analysis identified Albite, Quartz, and Aluminum Oxide as the main crystalline phases in Melati 02. ImageJ-based optical microscopy confirmed the presence and area distribution of these minerals. The crystallinity of the sample was determined to be 55.53%, suggesting a polycrystalline nature with moderate amorphous content. This study confirms that the dominant rock type in the area is feldspar-rich silicate rock, with potential geological and material science significance

1. Introduction

Mineralogical exploration plays a critical role in understanding the composition, structure, and potential utilization of geological materials. Rocks, as naturally occurring aggregates of minerals, exhibit unique physical and chemical characteristics depending on their origin and formation history. These characteristics are essential for interpreting regional geology, assessing natural resource potential, and developing materials for industrial applications [1]. In particular, silicate-rich rocks, such as feldspar and quartz-bearing formations, are commonly found in continental crust and are vital in ceramics, glass, and construction materials industries.

To accurately characterize the mineralogical content of rocks, advanced analytical methods are often employed. Scanning Electron Microscopy coupled with Energy Dispersive Spectroscopy (SEM-EDS) enables surface imaging and elemental analysis at micro and nanoscale resolution. This method is particularly effective for identifying elemental distributions and associating them with specific mineral phases (Chairunnisa & Wardhana, n.d.). Meanwhile, X-Ray Diffraction (XRD) remains a standard technique for determining the crystalline structure of minerals. XRD can identify individual mineral phases based on their unique diffraction patterns, quantify their abundance, and evaluate their degree of crystallinity [2]. These instrumental techniques are commonly complemented with optical microscopy and image analysis, which provide visual information on mineral grain morphology and textural relationships in the rock matrix [3].

The present study focuses on rock samples collected from Mangguliling Nature Park, located in Segeri District, Pangkajene and Islands Regency, South Sulawesi, Indonesia. The region lies within a broader karstic landscape known for its limestone caves and silicate-bearing outcrops. The site features exposed rocks with visible mineral variations, offering an ideal natural laboratory for mineralogical exploration. Although previous studies in the region have emphasized limestone characteristics, the current investigation targets feldspar-rich silicate rocks, which remain under-characterized in this specific geological setting.

This research aims to analyze the elemental composition, crystalline phases, and microstructure of selected rock samples using a multi-instrumental approach that integrates SEM-EDS, XRD, and optical microscopy. By doing so, this study not only contributes to the mineralogical mapping of the Mangguliling area but also demonstrates the effectiveness of integrated characterization techniques in understanding local geological resources.

2. Experimental Method

The study was conducted through a series of well-structured stages, beginning with field exploration and ending with laboratory-based characterization. The rock samples were collected from Mangguliling Nature Park, located in Segeri District, Pangkajene and Islands Regency, South Sulawesi, Indonesia, on November 2–3, 2024. The selection of this site was based on its exposed rock outcrops and mineralogical diversity, particularly the presence of feldspathic and silicate-rich rocks. Two representative rock samples were selected and labeled as Melati 01 and Melati 02.

Following field collection, the samples were subjected to mechanical preparation in the laboratory. Each sample was cut using a diamond blade into rectangular slabs measuring approximately 2 × 2 cm and 1.8 × 1.8 cm, with a final thickness of 2 mm. The samples were then polished sequentially using abrasive sandpapers with grit sizes of 100, 1000, and 1500 to produce flat, smooth surfaces suitable for microscopic and crystallographic analysis.

The first characterization technique performed was Scanning Electron Microscopy coupled with Energy Dispersive Spectroscopy (SEM-EDS). This test was conducted on November 7, 2024, using the polished solid slabs. SEM was employed to observe the surface topography and microstructure of the samples at high magnification, while EDS was used simultaneously to obtain qualitative and semi-quantitative elemental compositions. Prior to the analysis, the samples were cleaned and coated with a thin layer of conductive material (e.g., carbon or gold) to prevent charging during electron beam exposure.

The second method utilized was X-Ray Diffraction (XRD), conducted on November 9, 2024, to identify the crystalline phases present in the rock samples. The analysis was performed using a diffractometer equipped with a Cu-Kα radiation source ($\lambda = 1.5406$ Å). The scanning was carried out in a 2θ range of 10° to 70°, with a step size of 0.02°. The data obtained were processed using HighScore Plus software, which enabled phase identification through pattern matching with the ICDD (PDF-4+) database [4].

The third technique applied was optical microscopy, performed on November 14, 2024, to observe the surface morphology and grain textures under visible light. Microscopic observations were conducted at magnifications ranging from 50× to 1600× using a compound light microscope. Images were captured using a digital camera attached to the eyepiece and subsequently analyzed using ImageJ software. The analysis included measurements of particle area, distribution, and intensity contrast to aid in mineral phase differentiation .

All instrumental results were recorded and processed using supporting software tools including Origin for data plotting, ImageJ for microstructural analysis, HighScore Plus for diffraction pattern evaluation, and Microsoft Excel for tabulation and comparison [5] .

3. Results and discussion

This section presents the results obtained from the three major characterization techniques used to analyze the rock samples from Mangguliling Nature Park: SEM-EDS, optical microscopy with image analysis, and XRD. Each method provided a different but complementary set of information regarding the elemental composition, microstructure, and crystalline phases of the rock samples.

3.1 SEM-EDS Analysis

The elemental composition of the samples was obtained through Energy Dispersive Spectroscopy (EDS), integrated with Scanning Electron Microscopy (SEM). The EDS results show that Melati 01 was dominated by oxygen (O) at 45.5%, followed by carbon (C) at 14.9%, magnesium (Mg) at 14.0%, silicon (Si) at 13.6%, and iron (Fe) at 6.5%. Other minor elements identified include calcium (Ca), sodium (Na), and chlorine (Cl), indicating a mixture of silicate and oxide minerals.

For Melati 02, the EDS spectrum showed the highest concentration of oxygen (50.5%), followed by silicon (25.6%), carbon (16.4%), and aluminum (4.7%), along with traces of potassium (K), sodium (Na), and iron (Fe). The abundance of Si, Al, and O in Melati 02 is typical of feldspar minerals, such as albite ($NaAlSi_3O_8$), and quartz (SiO_2).

Table 3.1 EDS Results of Melati 01

Melati 01		Melati 01	
Elements	Wt%	Elements	Wt%
O	45.5	O	50.5
C	14.9	Si	25.6
Mg	14.0	C	16.4
Si	13.6	Al	3.6
Fe	6.5	Na	2.8
Ca	4.7	K	0.6
Al	0.6	Fe	0.3
Ni	0.1	Ca	0.2
Au	0.1	Ti	0.1

These elemental data confirm that the rock samples are silicate-based, with a matrix rich in aluminum and magnesium oxides. The elemental signature suggests the coexistence of both primary and secondary mineral phases in the studied rocks.

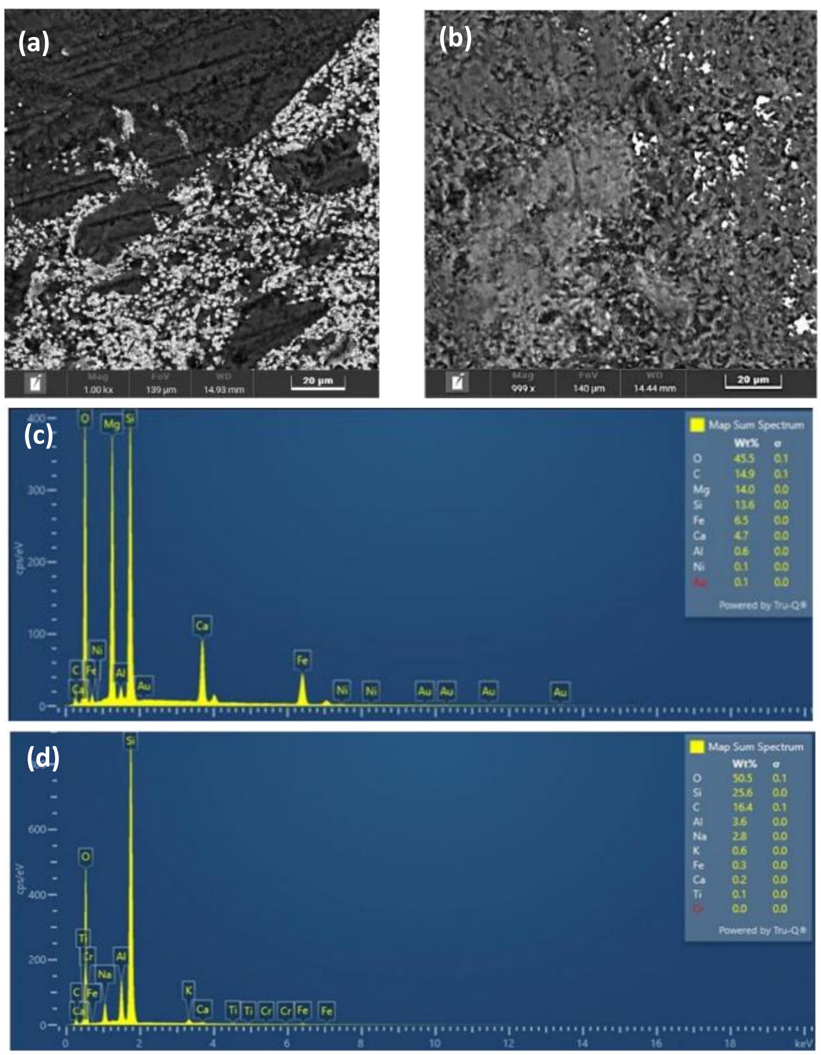

Figure 3.1 SEM images of (a) Melati01, (b) Melati02, EDS of (c) Melati01, (d) Melati02

3.2 Optical Measurements

Optical microscopy, supported by ImageJ analysis, was used to study the grain morphology and surface texture of Melati 02. The image analysis identified distinct mineral phases based on particle brightness and grain boundary contrast. Five mineral phases were differentiated: Quartz**,** Potassium Oxide (K_2O)**,** Albite**,** Magnetite (Fe_3O_4)**,** and Aluminum Oxide (Al_2O_3) [6].

The particle sizes and mean intensities for each phase were measured from microscope images: Quartz**:** Area = 1.515 mm^2, Mean intensity = 181, Potassium Oxide: Area = 0.971 mm^2, Mean intensity = 155, Albite: Area = 0.795 mm^2, Mean intensity = 150, Magnetite: Area = 0.352 mm^2, Mean intensity = 133, Aluminum Oxide: Area = 0.207 mm^2, Mean intensity = 106

These results suggest that quartz and albite dominate the surface mineral composition, while magnetite and aluminum oxide appear as smaller, dispersed grains. Differences in light intensity and grain size helped to differentiate between phases.

The optical observations complement the XRF/EDS findings and visually confirm the heterogeneous mineral makeup of the sample, reinforcing the presence of feldspathic and oxide components in the rock.

3.3 XRD Analysis

Ray Diffraction (XRD) analysis was performed to determine the crystalline phases of Melati 02. The XRD diffractogram displayed sharp and well-defined peaks, indicating a moderate degree of crystallinity. Phase identification using HighScore Plus software and the ICDD PDF-4+ database revealed the presence of: Albite ($NaAlSi_3O_8$) – 62%, Quartz (SiO_2) – 17%, Aluminum Oxide (Al_2O_3) – 17%, Minor phases: Potassium Oxide and Iron Oxide (unspecified)

The strongest diffraction peaks were located at 2θ = 27.9°**,** 26.6°**,** and 25.2°, corresponding to quartz and albite reflections. The degree of crystallinity was calculated to be 55.53%**,** while the average crystallite size, estimated using the Debye-Scherrer equation, was approximately 0.63 nm**.**

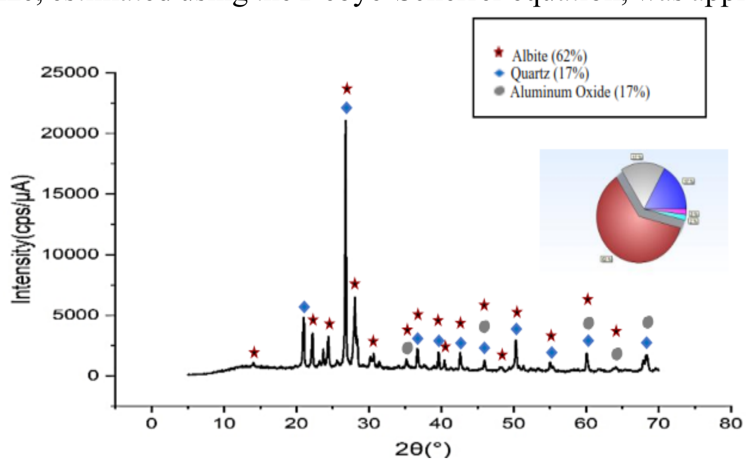

Figure 3.2 XRD Pattern of Melati02

The high proportion of albite and quartz confirms the classification of the sample as a feldspar-rich silicate rock, which is geologically consistent with the karstic setting of the Mangguliling area. The presence of aluminum and iron oxides as minor phases adds further complexity to the mineral structure, potentially influencing the physical properties of the rock [7].

4. Conclusion

The mineralogical characterization of rock samples from Mangguliling Nature Park using SEM-EDS, XRD, and optical microscopy has revealed that the rocks are predominantly composed of silicate minerals, especially albite and quartz, with additional phases such as aluminum oxide, potassium oxide, and magnetite. The elemental analysis confirmed a dominance of oxygen, silicon, aluminum, and other supporting elements typical of feldspar-rich rocks. The XRD results indicated a moderate degree of crystallinity, while microscopic analysis confirmed the heterogeneous grain distribution and surface texture. Collectively, these findings classify the sample as a feldspathic silicate rock, contributing valuable insight into the geological complexity of the region and offering potential for further exploration in materials science and resource utilization.

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