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Analysis of Mineral Types, Density, and Porosity in the Lam Teuba Formation Using Infrared Spectroscopy Method

Zahratun[1*], Muhammad Isa[1], Didik Sugiyanto[1]

[1] Program Studi Magister Fisika, Department of Mathematics and Natural Sciences, Syiah Kuala University, Banda Aceh, Indonesia.

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Corresponding Author:
Zahratun
zahra.ican@gmail.com

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Abstract: The Lam Teuba Formation is one of the local fault areas of the Seulimuem segment located in the Grand Mosque sub-district of Aceh Besar regency. The Lam Teuba Formation has several types of rocks such as basaltic andesite lava, pyrolastic flows, pyroclastic falls, and sedimentary rocks, namely claystone, limestone sandstone, agglomerate, limestone. Rocks have physical characteristics, namely density and porosity which have different values in each rock. This difference can be caused by the minerals contained in the rock. The method used to calculate the density and porosity values used the Archimedes method, and the identification of mineral types using *the infrared spectroscopy method*. The results of data processing obtained the highest original density value at location 1 sample 1 with a value of 3.42 and the lowest value at location 5 sample 2. The highest dry density value was in location 1 of sample 1 with a value of 3.33 and the lowest value was in location 5 of sample 2. The highest saturation density value was in location 1 of sample 1 with a value of 3.43, the lowest value was in location 5 of sample 2 with a value of 2.07. The average porosity value was the highest with a value of 5.41 in the poor quality category in sample 4, while the lowest value was 4.62 in the very bad category in sample 1. The types of minerals found in the Lam Teuba formation are *illite, montmorillonite, kaolinite* minerals with a mixture *of smectite* which is a clay mineral group and *siderite* minerals which are carbonate mineral groups.

Keywords: Infrared spectroscopy; Lam Teuba; Minerals; Physical properties; Rocks

Introduction

The confluence of the Eurasian and Indo-Australian plates creates a subduction zone on the western island of Sumatra (Metrikasari & Choiruddin, 2021; Razi, 2007). The confluence of the plates formed the Semangko Fault along the Bukit Barisan Mountains from Semangko Bay to the northern Aceh region as far as 1900 Km which is divided into 20 active segments such as the Aceh segment and the Seulimum segment (Mulyaningsih, 2018). In the Seulimum segment there are several local faults in the Lam Teuba formation. In the Lam Teuba formation, there are several types of rocks such as basaltic andesite lava, pyrolastic flows, pyroclastic falls, and sedimentary rocks, namely clay rocks, limestone sandstones, agglomerates, limestone (Asrillah et al., 2014; Hidayatullah, 2010; Ismail & Marwan, 2019; Sota, 2011).

The rock has several characteristics such as chemical properties, mechanical properties and physical properties (Huang et al., 2021; Siegesmund & Dürrast, 2010). In this study, the discussion study only includes the physical properties of rocks, namely the density and porosity of rocks. Each rock has different characteristics such as density value, saturation, porosity, permeability, compressibility and heat capacity (Fajrina, 2016; Habibirahman et al., 2019; Hafsari & Rading, 2017).

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Density is a physical property that describes the bond density of the materials that make up the rock. Density is classified into three, namely native density, dry density and saturated density (Jaques et al., 2020; Manatunga et al., 2021; Oesanna et al., 2018). Porosity is the ratio of pore volume to total volume (Hook, 2003; Jaya et al., 2020). The movement that occurs in the fault area causes the rock to be less consolidated so that the density value is poor compared to the surrounding area. This can cause the area to be prone to disasters. Therefore, it is necessary to calculate the density and porosity values of the rocks in the Lam Teuba formation. The value of density and porosity is useful in fields such as oil and gas exploration, geotechnical engineering, mining and geological processes (Ronodirdjo et al., 2020; Zaini et al., 2021).

The difference in characteristics in the rock is also influenced by the type of minerals found in the rock (Du et al., 2022). The mineral content is composed of a collection of crystals and chemical elements with a fixed and regular arrangement, organic or inorganic that is naturally formed in nature, and in solid phases has a certain composition and structure (Krivovichev et al., 2022; Marwan et al., 2014; Sugiyanto et al., 2011). Minerals have millions of benefits in daily life, in the fields of construction, health, jewelry and so on. Minerals in the fault area have high economic value, because the fault is the exit route of magma to the surface and carries high-value minerals (Pontual et al., 1997). One of the methods that can be used in analyzing mineral types is the *infrared spectroscopy method.* Its working principle uses the interaction of electromagnetic waves on solid or liquid objects. These interactions will produce optical processes such as transmission, absorption, rejection and can produce spectral characteristics of a material (Sugiyanto et al., 2011).

Method

The method that can be used in analyzing mineral types is the *infrared spectroscopy method*. Its working principle uses the interaction of electromagnetic waves on solid or liquid objects. These interactions will produce optical processes such as transmission, absorption, rejection and can produce spectral characteristics of a material (Bradley, 1987; Winarto & Yulia, 2014; Zalzabila, 2022).

The research sample was taken in Ie Suum Village, Masjid Raya District, Aceh Besar Regency, Aceh Province. Sampling was carried out on the Lam Teuba fault line at five different coordinate points with the distance between the coordinate points being 300 meters as shown in Figure 1.

Furthermore, the samples were taken to the Mathematics and Natural Sciences laboratory Syiah Kuala University to be prepared for the next stage. The tools needed in calculating density and porosity values are measuring cups, analog balances, ovens and threads, hammers. The tool needed to identify the type of mineral is the FieldSpec spectrometer. The samples used are in the form of rocks that have been shaped into cubes and rocks that have been crushed. *The supporting software* in this study is RS3 software to control the instrument during measurement, Envi5.3 software to identify the type of mineral by matching the spectrum obtained, ViewSpecPro software to reduce *gaps* in the spectrum and Excel to help with data processing.

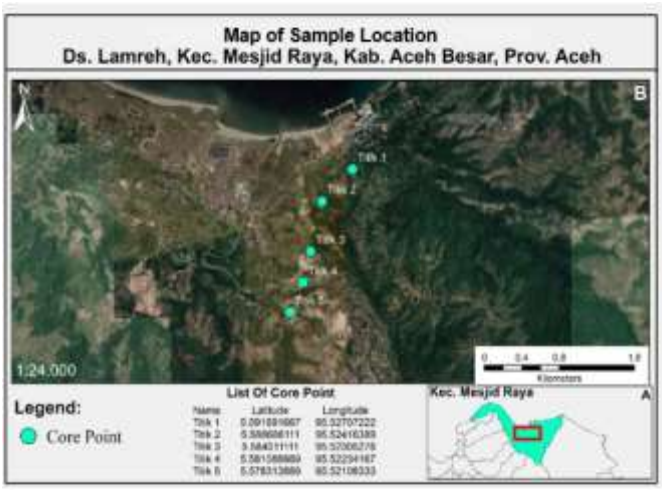

Figure 1. Research location

Calculating the Density and Porosity Values of Rocks

Figure 2. Rock samples

Density is the density between materials within a rock, while porosity is the empty space that is inside a rock. Before the treatment was carried out on the rock samples, the samples were first cut with a size of 2 cm x 1.5 cm x 1.5 cm as shown in Figure 2 and then tested for density and porosity using the Archimedes method. The values that are calculated are the original density value, namely the value of rocks that have not been treated, the dry density value, which is rocks that have been heated in the oven with a temperature of 150°C for 2 hours with 3 repetitions, the saturated density value, namely rocks that have been soaked in water for 72 hours and the porosity value.

The stages of the research can be seen in the flow chart figure 3.

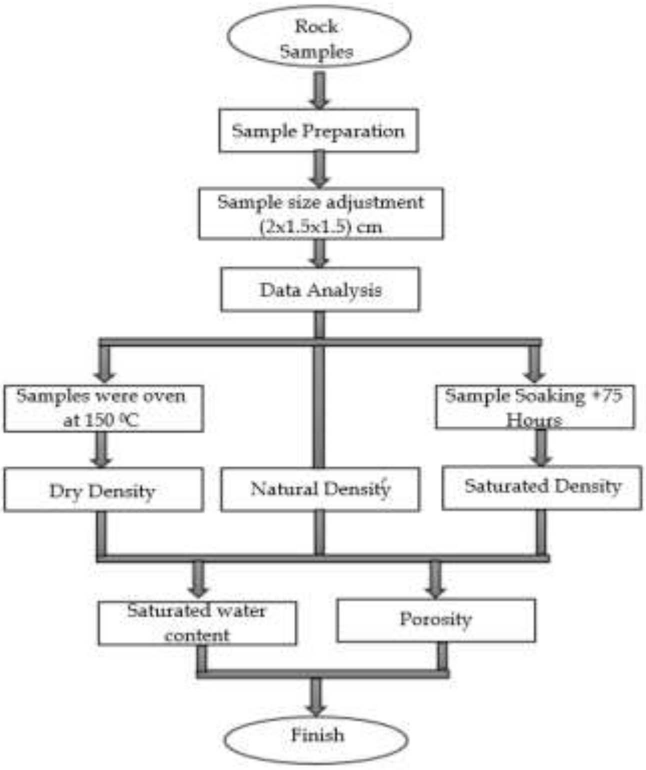

Figure 3. Diagram of the flow of the stages of density and porosity value analysis

Determining density and porosity values using the Archimedes method with equations (Habibirahman et al., 2019).

Saturated mass of sample in water

$$m_s = m_a - m_b \quad (1)$$

Sample volume without pores

$$V_p = \frac{m_o - m_s}{\rho_{ar}} \quad (2)$$

Natural density

$$\gamma = \frac{m_n}{v_b} \quad (3)$$

Dry Density

$$\gamma = \frac{m_o}{v_b} \quad (4)$$

Saturated *density*

$$\gamma = \frac{m_w}{v_b} \quad (5)$$

Saturated water content

$$w = \frac{m_w - m_o}{m_o} \times 100\% \quad (6)$$

Porosites

$$\varphi = \frac{m_w - m_o}{m_w - m_s} \times 100\% \quad (7)$$

Sample original mass (m_n), sample dry mass (m_o), sample saturated mass (m_w).

Identifying the Type of Minerals in Rocks

The rock samples were smoothed first and then filtered with a size of 80 mesh. The rock is crushed into smaller particles so that the given electromagnetic waves can be absorbed well and get a perfect spectral shape. The tools used are *FieldSpec4 spectrometers* and *RS3 software* to control the tools during the data collection process. Before use, the appliance is switched on and left to sit for approximately 15 minutes. The stages of the research can be seen in the flow chart Figure 4.

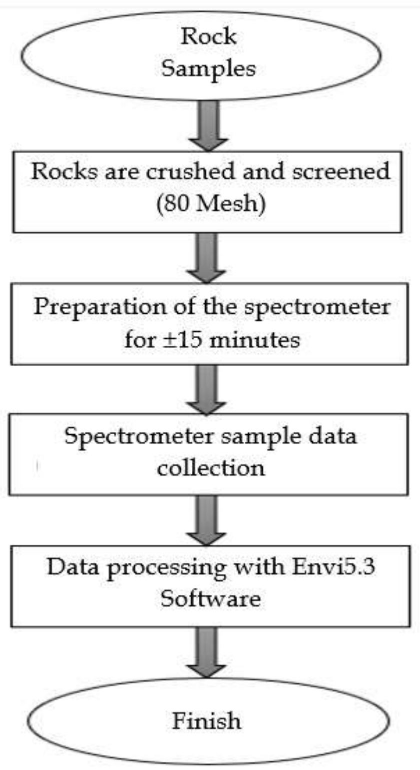

Figure 4. Flow diagram of the stages of mineral type identification

The data was taken using the *FieldSpec4* spectrometer measured *Near Infrared* (NIR), which is at a wavelength of 780 nm to 2500 nm. Rock samples are placed under the *contact probe*. The rays coming from the *contact probe* will hit the sample and the rays are absorbed by the sample, forwarded and reflected. The reflected light will hit the detector which will then be analyzed by *fieldspec4* and the results will be displayed on the laptop screen in the form of spectra by running *RS 3 software*.

Figure 5. Spectrometer range

The spectra obtained is then corrected using *ViewSpec Pro software* to reduce *gaps*. Then the corrected data is *uploaded* to the Envi5.3 software and the spectral *building*, *continuum removal spectral, spectral resampling,* and *spectral analysis* processes are carried out to compare the spectral data from the measurement results with the spectral data *of the United State Geological Survey* (USGS) *library* in the Envi5.3 software. Spectra compatibility is reviewed from the absorption position, spectral shape, and absorption features. The analysis was also carried out visually with a book guide from Pontual et al. (1997).

Result and Discussion

Analysis of Density and Porosity Values

The density and porosity values of a rock are determined by the density of the materials that make up the rock. Rocks with high density values have low porosity values and vice versa if the density value is low, the porosity value will be high. The density values of the analyzed rock samples were natural density, dry *density* and saturated *density*. Dry density, which is rock that has been in the oven for 2 hours with a temperature of 150oC, and saturated density, which is rock that has been soaked in water for 72 hours. The three density values can be seen in Table 1.

Based on Table 1, location 1 in sample 1 has a high original density value of 3.42 grams/cm3 and location 5 in sample 2 shows a low-density value of 1.75 grams/cm^3. The dry density value is a rock sample that has been heated in the oven so as to remove the moisture content in the rock, the highest value is shown at location 1 sample 1 with a value of 3.33 grams/cm^3 and the lowest value is shown at location 5 sample 2 with a value of 1.68 grams/cm^3. The saturation density value is a sample of rock that has been immersed.

Table 1. Density Value of Rock Sampoles of Lam Teuba Formation

Location	Original Density (gram/cm^3)			Dry Density (gram/cm^3)			Saturated density (gram/cm^3)		
	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
1	3.42	2.34	2.46	3.33	2.34	2.40	3.43	2.34	2.51
2	2.40	2.48	2.38	2.40	2.37	2.36	2.50	2.49	2.47
3	2.44	2.89	2.37	2.41	2.21	2.31	2.50	2.39	2.42
4	2.38	2.16	2.30	2.31	2.06	2.23	2.47	2.28	2.40
5	2.19	1.75	1.86	2.03	1.68	1.75	2.44	2.07	2.09

The density of the material is filled with fluid to the maximum. The highest saturation density value was found in location 1 sample 1 with a value of 3.43 grams/cm^3 and the lowest saturation density value was found in location 5 sample 2 with a value of 2.07 grams/cm3. Porosity is the pores found in rocks that are useful for storing fluids. The clarity of the porosity value in the rock sample can be seen in Table 2.

Table 2. Porosity Values in Lam Teuba Fault Rock Samples

Location	Water saturation level (%)			Porosity (%)		
	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
1	13.32	14.84	13.67	3.21	5.76	4.88
2	13.52	13.42	13.69	4.85	4.85	4.99
3	13.2	14.61	13.65	4.72	5.60	5.10
4	14.13	14.56	13.56	5.19	5.91	5.13
5	11.77	10.03	11.73	4.40	4.52	5.25

The porosity value is inversely proportional to the density value, if the high density value eats the low porosity value, on the other hand, if the density value is low, the porosity value will be high. The highest porosity value was at location 4 sample 2 with a value of 5.91% and the lowest porosity value was at location 1 sample 1 with a value of 3.21%.

Identify the type of mineral

There are four different types of minerals in the rock samples taken in the Lam Teuba formation. One of them is a group of carbonate minerals, namely in the sample of 1 type of siderite minerals with a chemical composition of OH, H2O, Mg-OH. Other minerals are a group of clay minerals such as *Kaolinite* with a mixture of *Smectite, Montmorillonite,* and *Illite* with the chemical composition of OH, H2O, Mg-OH, Al-OH. The form of absorption and wavelength position can be seen in Table 3.

Table 3. Composition and Types Of Minerals in Lam Teuba Fault Rock Samples

Sample	Absorption Position (nm)	Molecular Vibrations	Form	Types of Minerals
1	~1418	OH and H_2O	Single Feature	Siderite
	~1912	H_2O	Single Feature	
	~2300	Mg-OH	Double Feature	
2	~1415	OH and H_2O	Single Feature	Montmorillonite
	~1910	H_2O	Single Feature	
	~2209	Al-OH	Single Feature	
3	~1413	OH and H_2O	Single Feature	Illite
	~1911	H_2O	Single Feature	
	~2209	Al-OH	Single Feature	
	~2300 to 2400~	Mg-OH	Double Feature	
4	~1413	OH and H_2O	Single Feature	Illite
	~1910	H_2O	Single Feature	
	~2209	Al-OH	Single Feature	
	~2300 to 2400~	Mg-OH	Double Feature	
5	~1418	OH and H_2O	Single Feature	Kaolinitewith a mixture of
	~1916	H_2O	Single Feature	Smectite
	~2207	Al-OH	Double Feature	
	~2300 to 2400~	Mg-OH	Triple Feature	

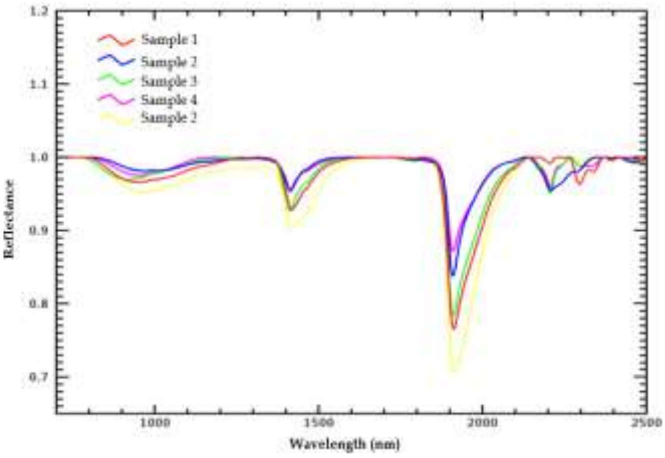

Figure 6. Spectra of rock samples in the Lam Teuba formation

After measurements were made using the FieldSpec4 Hi-Res spectrometer on five rock samples, showing different characteristics in each sample. Differences in spectral characteristics occur in the position of wavelengths, shapes, and abstract features. It can be seen in Figure 6 that there are several absorptions that occur, such as a wavelength of 1400 nm showing the presence of absorption caused by OH and H ~ 2O molecules where the deepest absorption occurs in sample 5. At ~ the wavelength of 1900 nm, there was absorption caused by water molecules (H_2O) that were wide and deep, the most absorption occurred in sample 5. At the wavelength of 2200 nm, it shows the absorption of Al-OH molecules which is a characteristic of clay minerals, the spectral shape is wide and deep, sample 2 has a wide and deep absorption of Al-OH molecules compared to other samples. The wavelength shows the presence of wide and deep absorption of Mg-OH as shown by sample 1 ~~2300.

Conclusion

The five rock samples taken in the Lam Teuba formation had average porosity values of 4.62, 4.90, 5.14, 5.41 and 4.73. The porosity value has a very bad porosity quality to poor. The minerals obtained in the research area are clay mineral groups, namely *illite, montmorillonite, kaolinite* with a mixture of *smectite* and *siderite* minerals which are carbonate mineral groups. The Lam Teuba fault area is dominated by the clay mineral group which is a type of mineral alteration from the primary mineral K-Feldspar.

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Author Contributions

Conceptualization, Z.; methodology, M.I.; riset instrument, Z.; data retrieval, Z, M.I,D.S; data curation, Z.;writing—original draft preparation, Z; writing—review and editing, M.I, and D.S: visualization, M.I. S. and D.S: software, Envi5.3

and Excel. M.I and D.S. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest
The authors declare that there is no conflict of interest regarding the publication of this paper.

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