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Porosity Value Analysis of Limestone as a Groundwater Reservoir in West Kaidundu Village, Bulawa Sub-District, Bone Bolango Regency

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ABSTRACT

West Kaidundu is a village with diverse terrain conditions, covering high hilly areas, some lowlands, and coastal areas in Bulawa Sub-District, Bone Bolango Regency. The diverse morphological and geological conditions have an impact on the potential of natural resources, the distribution of limestone, and different geological structures.Research on the porosity of limestone is crucial to obtain information about its porosity value. A study analyzing the porosity of limestone in Kaidundu Barat Village has not been conducted before. Therefore, this research is significant and interesting to carry out at the study location. The results of the study reveal the geological conditions of the research area, which consists of three geomorphological units: pyroclastic ridge, karst plain, and alluvial plain units. The study area is composed of wackestone and mudstone limestone, pyroclastic breccia, and alluvial deposits. From the porosity analysis, the wackestone limestone in the study area, categorized as reservoir rock, falls into the poor category, while the mudstone limestone is classified as fair.

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1. INTRODUCTION

Sulawesi is a K-shaped island in central Indonesia. The world's main plates are the Indo-Australian Ocean, the Pacific Ocean, and the Eurasian Ocean. The geological conditions in the North Arms of Sulawesi, especially the Gorontalo area, are very complex because they are part of the volcanic-plutonic path. The geological complexity of Gorontalo is reflected in the interpretation of the tectonic location of active faults in three locations associated with the Gorontalo Geological Map and the matching of seismic data. The tectonic impact of uplift is limestone in the Limboto Basin, which experienced an uplift of 0.0699-0.0724mm/year (Apandi & Bachri, 1997; Permana et al, 2019; Marfian et al, 2023; Mooduto et al; Panaai et al, 2024; Robot et al, 2024; Suratinoyo, et al 2924)..

The geological conditions in the southern part of Gorontalo are very complex. Complexity is related to the diversity of lithology, geomorphology, and geological structure. The distribution of limestone on the south coast of Gorontalo and Tomini Bay is unique among volcanic rocks (Mane et al, 2024; Hisbulah et al, 2024).

West Kaidundu is a village with diverse terrains, including hilly/highland areas, some lowlands, and coastal areas. In addition, morphological and geological conditions in Gorontalo are diverse, including the potential of natural resources, the distribution of limestone, and different geological structures (Eraku & Baruadi, 2023). The research area has a limestone unit lithology with the surrounding lithology, namely the Pinogu volcanic rock unit. The limestone of the study area is included in the Holocene Ql formation (Partoyo et al., 1997).

Previous research was conducted by Permana & Eraku (2020) in the West City area, Gorontalo City, namely the Quality of Gorontalo Limestone as a Groundwater Reservoir Based on Porosity Type Analysis. In this area, research has also been carried out by Pangulu et al. (2022), who explained that this area has limestone units. The difference between the previous research and this study is the location and research method used.

Previous research used field survey methods and petrographic analysis. Meanwhile, this study added a specific gravity test analysis method. Research on limestone porosity is fundamental to obtaining information about its porosity value. Research on the analysis of limestone porosity value in West Kaidundu village has never been conducted. Therefore, this research is interesting to be conducted at the research location. Based on this background, the aim of this study is to analyze the porosity value of limestone in West Kaidundu Village, Bulawa District, Bone Bolango Regency.

2. METHOD

Administratively, the research location is in West Kaidundu Village, Bulawa District, Bone Bolango Regency (Figure 1). In this study, two approaches are used, namely qualitative and quantitative approaches. The qualitative method was chosen because it will evaluate and compare existing theories to obtain information in the form of data on geology and types of porosity. The quantitative approach was chosen because this study involved petrographic analysis and calculation of limestone porosity values in West Kaidundu Village (Triyani et al, 2024; Wowiling et al, 2024; Permana et al, 2024a).

At this stage, the analysis was conducted at the Soil Mechanics Laboratory, Department of Civil Engineering, Universitas Negeri Gorontalo. This analysis aimed to determine the specific gravity

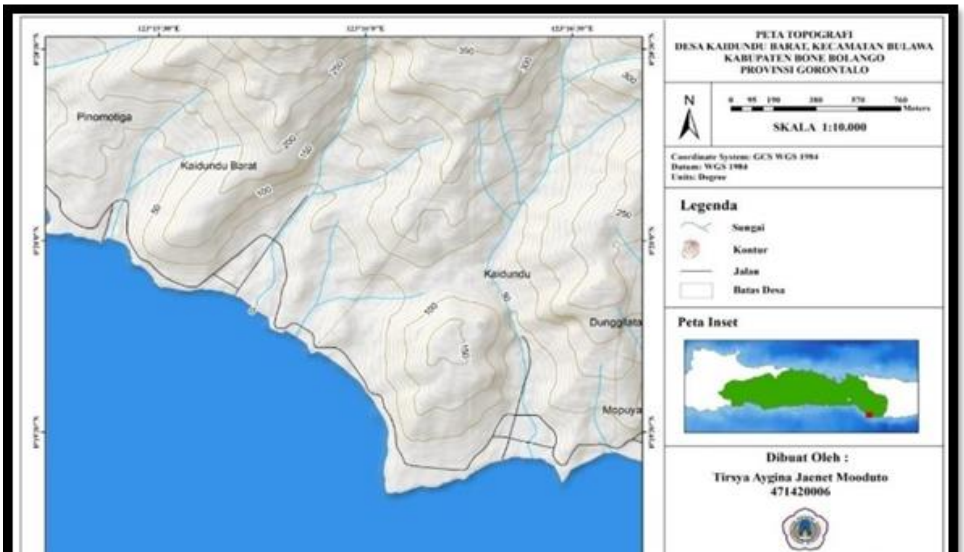

Figure 1. Map of the research location.

of limestone, which would subsequently be used to calculate its porosity. The analysis followed the standard reference of SNI 1969:2008 (Badan Standarisasi Nasional, 2008) on the Method for Testing Specific Gravity and Water Absorption of Coarse Aggregatse. Several tools were utilized in this analysis, including:

1. Oven capable of adjustable temperatures up to (110±5)°C.

2. Scale with 0.1% accuracy and a maximum capacity of 5 kg, equipped with a device to suspend a basket or sample holder underwater at the center of the scale.
3. Sample holder, a wire basket with a mesh size of 3.35 mm or adjusted to fit the test sample size.
4. Water tank, a watertight tank in which the sample and sample holder can be fully submerged while suspended under the scale.
5. Suspension device, a wire used to suspend the sample holder and the test sample.
6. Tray, a container for holding the test sample.
7. Test sample, limestone samples collected from the research location.

After that, the analysis procedure is:

1. Drying: The first step involves drying the sample in an oven at a temperature of (110±5)°C for (24±4) hours.
2. Cooling: The sample is then cooled at room temperature for 1-3 hours.
3. Weighing (dry weight): Once cooled, the sample is weighed to obtain its dry weight.
4. Saturation: The sample is soaked in a water-filled tray for (24±4) hours.
5. Weighing (saturated surface dry weight): After soaking, the sample is removed from the water, rolled on an absorbent cloth or sheet to remove visible surface water, and then weighed to determine its saturated surface dry weight.
6. Weighing (submerged weight): The sample is placed in the sample holder, suspended in water, and weighed to obtain its submerged weight.

Once the rock weights in various states are obtained, calculations are performed using formulas based on SNI 1969:2008 for specific gravity and the porosity formula from (Wiloso & Ratmy, 2018; Permana et al, 2023; 2024b).

$$Porosity\ (\%) = \frac{W_w - W_o}{W_w - W_s} \times 100\% \quad (1)$$

This comprehensive process ensures accurate measurement and analysis of limestone properties relevant to its function as a reservoir rock. Where there are several stages of research. The literature study is carried out in the preliminary stage by examining preliminary study of the regional geology of the research area and the interpretation of the map topographic to see the landscape and determine the course of lithological mapping then the data collected from the field is then processed and analyzed in the laboratory, including geomorphological analysis, stratigraphic analysis, petrographic analysis and specific gravity analysis.

3. RESULTS AND DISCUSSION

The results of this study were to analyze the potential porosity of limestone by using two analysis methods, namely porosity analysis using petrographic analysis to analyze limestone porosity so that the potential of limestone as a reservoir rock can be obtained based on the classification of Koesomadinata (1980) and using the method of specific gravity analysis and coarse aggregate water absorption to analyze the porosity value of rocks. The results of geomorphology based on the classification of Brahmantyo & Bandono (2006) divided the research data into 3 units: pyroclastic flow ridges, karst plains, and alluvial plains.

3.1. Pyroclastic Ridge Unit

This pyroclastic ridge unit covers ± 60% of the area of the research location. Referring to slope analysis, this geomorphological unit has a morphometric value of 0-45%, influenced by exogenous processes by erosion and weathering as well as endogenous processes in the form of tectonism and volcanism, the materials that make up the unit This is a volcanic product, namely pyroclastic rock which is fine tuff. Direct validation results show that this area is a forest area and local plantations (Figure 2).

Figure 2. Pyroclastic Ridge Unit, Relative to the Southeast

3.2. Karst Plain Unit

This plain unit is south of the research location and occupies 25% of the total area of the research area. This geomorphic unit is composed of sandy limestone and layered limestone (wackestone) with a flat topography with a slope of less than 5% and an elevation of 10 to 15 meters above sea level (Devy, 2017) (Figure 3).

Figure 3. Karst Plain Unit

3.3. Alluvial Plain Unit

Alluvial plain units are composed of fine-grained materials such as clay and silt to boulders. The alluvial plain unit occupies approximately 15% of the total area of the study area (Figure 4).

Figure 4. Alluvial Plain Unit, Relative North Image direction

The limestone in the study area consists of four types of limestone, wackestone, and mudstone. The type of wackestone itself is found in three rocks. This rock has a brownish-yellow color, which indicates that the condition is fresh, and at the top, there are signs of weathering outcrops; namely, the color of the rock is slightly blackened, the grain size is >2 mm, and the compact and open container (Figure 5).

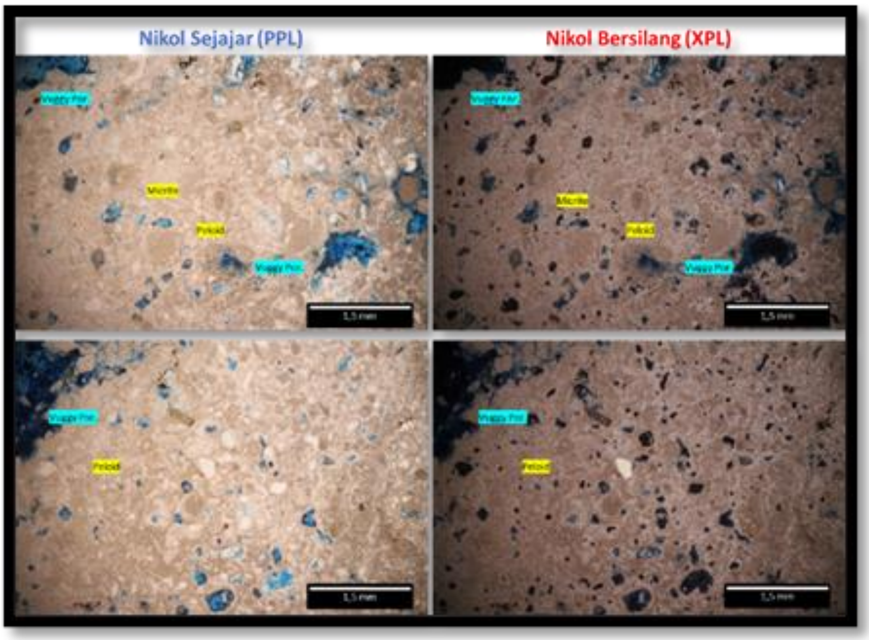

Figure 5. Appearance of Wackestone Limestone Outcrop (Station 1)

Figure 6. Appearance of Wackestone Limestone Outcrop (Station 4)

Microscopically, carbonate rocks are brown, mud supported, have grain sizes varying between <0.5-1 mm, the main composition is in the form of peloids and plagioclasts with a matrix in the form of micrite. The peloid is brown, <1mm in size, 17% abundance, Plagioclase is white showing twinning, 5% mycrite abundance is brown, 72% abundance. Petrographic analysis under the microscope, in the ST1 wackestone sample, this incision has a vuggy porosity type, interparticle porosity is also found, namely porosity found between limestone grains. The porosity of this rock is only 3.79%. (Embry & Klovan, 1971)

This rock occupies a karst plain with a flat slope and itund on public roads. Some outcrops are found in a state of decay. This outcrop is in a condition that is starting to rot, which is characterized by a slightly blackened rock color and some brownish-white color, grain size < 2 mm, mud supported, compact, well sorted (Figure 6).

Microscopically, carbonate rocks are light brown, mud-supported grain material consisting of a size of 0.5-1.5 mm; the composition of the grain is in the form of peloids, and the matrix is in the form of micrite. The peloid is brown, observed to arrange many rocks with a degree of subrounded to rounded vegetation, size 0.5 mm to 1.5 mm, and abundance (25%). In the ST4 wackestone sample, a relatively high amount of porosity was found with the type of vuggy porosity; the primary porosity observed was interparticle, the secondary porosity observed was vuggy porosity, where the matrix in the form of micrite amounted to 25% and sparite amounted to 50%. The porosity in this rock is 7.07% (Figure 7).

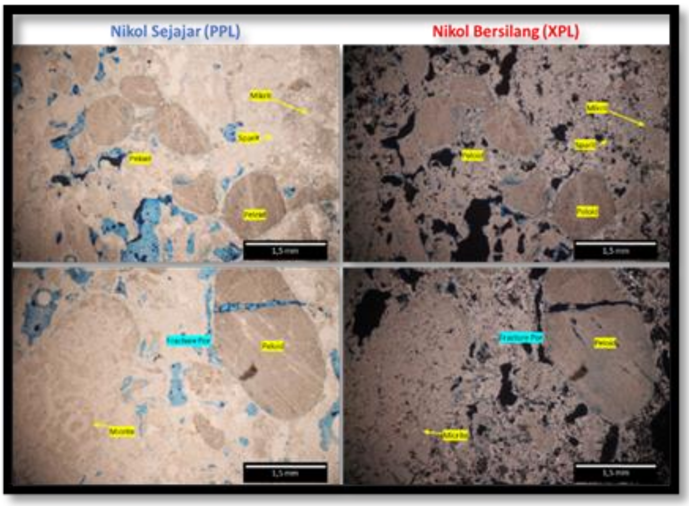

Figure 7. Petrography Analysis of ST4 Wackestone

Figure 8. Appearance of the Wackestone Limestone Outcrop (Station 5)

This outcrop is in a weathered condition which is characterized by a slightly blackened rock color and some brownish-white color, grain size < 2 mm, mud-supported, compact, well sorted (Figure 8).

Microscopic method, carbonate rocks are light brown and dark brown, mud-supported, have grains between 0.5-2mm, skeletal sgrain composition in the form of ooids, peloids, skeletal grains, foraminifera, matrix in the form of micrite. Brown ooids, <0.5 mm in size, have an abundance of 5%. The peloid is brown, size <0.5mm, abundance 7%. Skeletal grain is <1mm in size, 7% abundance. The clast is <1mm in size, light brown and whitish-black, 2% abundance. The mycrit is brown, with an abundance of 77%. Foraminifera has a size of <0.1mm of 2% abundance. The observed porosity is vuggy. (Embry & Klovan, 1971). In the ST5 wackestone sample, in this rock there is a matrix in the form of mycrite, amounting to 82%, which shows that the recrystallization process that occurs is still small and the porosity of this rock is 2.61% (Figure 9).

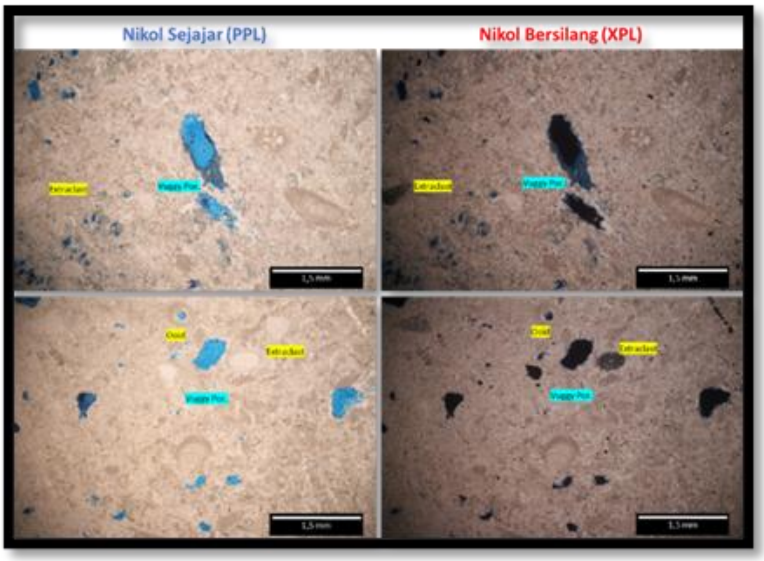

Figure 9. Petrography Analysis of ST5 Wackestone

Figure 10. Appearance of Mudstone Limestone Outcrop (Station 8)

This outcrop is in a weathered condition which is characterized by a slightly blackened rock color and some brownish-white color, grain size < 1mm, mud-supported, compact, and well sorted (Figure 10).

Based on microscopic observations, it was found that carbonate rocks were light brown and blackish-brown, mud-supported, the grain size was observed <0.3mm, the composition consisted of peloid material, and the matrix was in the form of mycrite. Peloid is blackish-brown, size <0.5mm, abundance 2%. The mycrit is light brown, 98% abundance. The observed porosity is vuggy porosity. (Embry & Klovan, 1971). In the ST8 mudstone sample, it has a high porosity with porosity types namely vuggy and interparticle, proving that the dissolution is quite high in the rock. With a matrix in the form of a mikrit with a value of 98%. The porosity value is 6.18% (Figure 11).

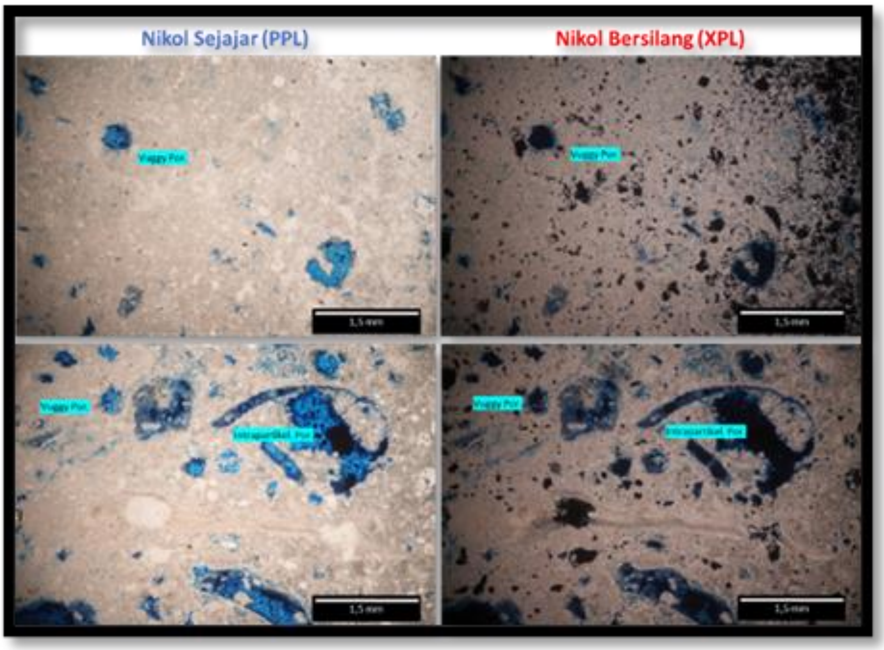

Figure 11. Mudstone ST5 Petrography Analysis

Then in porosity based on specific gravity analysis, it was found that the porosity value of ST1 wackestone limestone was 10.26%, ST4 wackestone limestone was 10.48%, ST5 wackestone limestone was 6.57% and mudstone limestone was 16.5% (Table 1)(Figure 12).

The porosity value obtained from the average value of the two analysis methods has the same relationship between porosity and limestone grain size as the porosity value of the results of the petrographic analysis. Based on figure 5, it shows that the porosity value is decreasing along with the rougher grain size on the limestone.

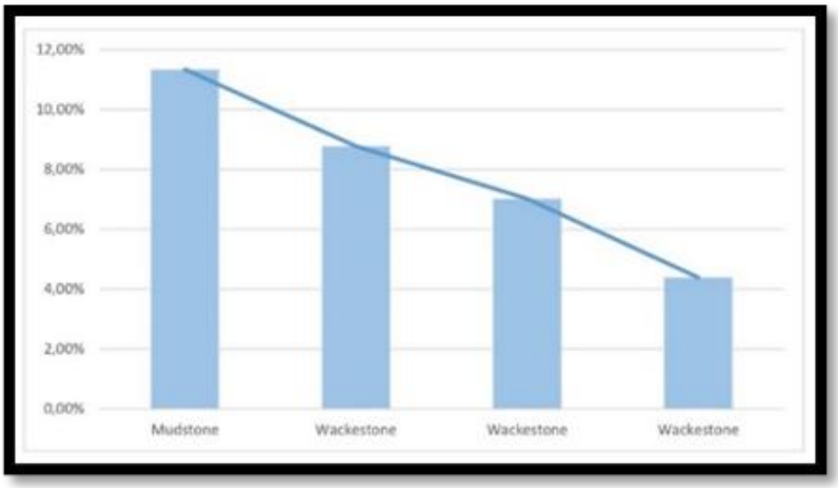

Figure 12. Relationship between porosity and uniformity of limestone grains

Table 1. Porosity Value of Limestone from Two Analysis Methods

No	Station No.	Rock Name	Porosity (Petrography)	Porosity (Specific Gravity)	Average	Porosity (Koesomadinata, 1980)
1.	ST 1	Wackestone	3,79 %	10,26 %	7,025 %	Bad
2.	ST 4	Wackestone	7,07 %	10,48 %	8,775 %	Bad
3.	ST 5	Wackestone	2,61 %	6,57 %	4,59 %	Negligible
4.	ST 8	Mudstone	6,18 %	16,5 %	11,34 %	Enough

4. CONCLUSIONS

The geomorphology of the research area consists of pyroclastic flow ridge landforms, karst plain landforms, and alluvial plain landforms. The research area is divided into pyroclastic breccia rocks, wackestone limestones, mudstone limestones and alluvial deposits.

The results of the analysis of the porosity value of limestone in West Kaidundu village as a reservoir rock in ST-1 wackestone limestone are in the poor category, ST-4 wackestone limestone is also in the poor category, ST-5 wackestone limestone is in the negligible category, and mudstone limestone ST-8 is included in the sufficient category. Based on the results of the porosity analysis, the limestone in West Kaidundu Village cannot be used as a groundwater reservoir because it has a low porosity value.

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