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Potential of Limestone as a Groundwater Reservoir based on Porosity Analysis in the Tintingon Area, Banggai District

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Abstract

The research area is in Tintingon Village, Banggai Regency, Central Sulawesi Province. This study aims to determine the quality of limestone as a groundwater reservoir based on porosity analysis. This study begins with sampling limestone at seven stations, then selecting fresh samples for laboratory analysis. Laboratory analysis consists of two, namely petrographic analysis and porosity analysis. The petrographic analysis aims to determine the microscopic naming of limestone and the type of pores in the rock. Porosity analysis aims to test the ability of limestone to accommodate fluids as a groundwater reservoir. Based on the petrographic analysis, it is known that the microscopic naming of limestone in the study area is wackestone and packstone. The types of limestone porosity are vug, intercrystal, channel and interparticle. Analysis of limestone porosity in the study area is known to be 15.24 – 29.95%. The porosity value is categorized as good to excellent so the research area is very good as a groundwater reservoir rock.

Keywords: groundwater; limestone; porosity; reservoir; Tintingon.

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Introduction

Limestone is a sedimentary rock composed mostly calcium carbonate ($CaCO_3$) (Ali & Ahmed, 2019; Santika & Mulyadi, 2017). These rocks come from the remains of marine organisms (Aryaseta et al., 2022). Limestone aquifer lithology formations have flow media characteristics in the form of pores, fractures, and dissolution passages, so they have the potential to drain groundwater at high speeds (Febriarta et al., 2020).

One that affects the availability of groundwater in limestone areas is the presence of pores in the rock. Porosity is a measure of the volume in the rock available to accommodate the reservoir fluids. Therefore, the volume of oil, gas and water in each reservoir depends directly on the porosity (Oyeneyin, 2015). However, carbonate reservoirs are generally characterized by strong heterogeneity, making the exploitation and prediction of prolific reservoirs difficult (Makhloufi et al., 2013; Matonti et al., 2015; Corbett et al., 2017). The heterogeneity of carbonate reservoirs is closely related to their pore morphology and pore connectivity. However, these properties are difficult to determine (He et al., 2016).

Limestone can be used for various needs, both industrial and household needs (Okto et al., 2021). Several studies on limestone have been conducted on Sulawesi Island, including Nurwaskito et al. (2015) who examined the quality of limestone as the main raw material for Portland Cement in South Sulawesi. Permana (2018) examined the quality of limestone as an industrial mineral in Gorontalo. Yoanita et al. (2016) conducted research in Central Sulawesi on the study of gypsum synthesis from limestone and research on limestone as a raw material for cement in Gorontalo conducted by Eksan et al. (2019). All of researchers jointly studied the benefits of limestone in the industrial sector. The potential of limestone is not only from an industrial perspective but also from an environmental sustainability perspective as a groundwater reservoir reserve.

Research on the quality of limestone as a groundwater reservoir on the island of Sulawesi, especially in the city of Gorontalo, has been carried out by experts. The results showed that the potential of limestone in the city of Gorontalo as a groundwater reservoir is in the very good category with a porosity of 20–25% (Permana & Eraku, 2020). According to Munawir et al. (2019) who conducted research on aquifer analysis in limestone based on secondary porosity in Lam Kabeu – Pidie, concluded that the porosity value in the area is between 5–45%. Limestone that has not been classified will have a smaller porosity value between 0–10%. Another study conducted by Wiloso & Ratmy (2018), concluded that limestone at the research location with a porosity value of 22.23% could be an excellent aquifer.

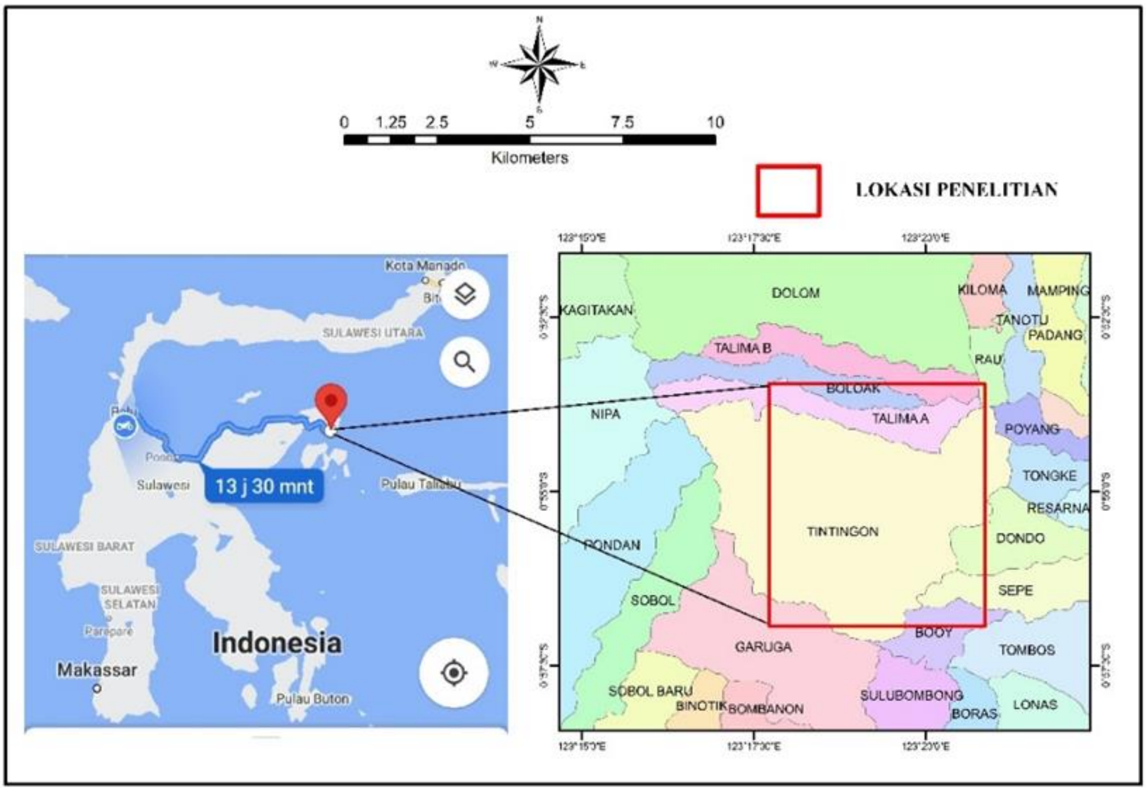

Figure 1. Location of the research area (the red box).

Limestone in Central Sulawesi has not been properly utilized (Yoanita et al., 2016). Research on the quality of limestone as a groundwater reservoir in Central Sulawesi has never been carried out, especially in the Tintingon area, Balantak Selatan District, Banggai Regency (Figure 1). The limestone in this area is close to community settlements and is one of the reasons research projects for the availability of groundwater reservoirs needs to be carried out. This is to support the need for clean water as a basic need for the local community. The purpose of this study was to determine the potential of limestone as a groundwater reservoir based on porosity analysis. The Tintingon area is included in the Salodik Formation based on the geological map of the Luwuk sheet. The Salodik Formation consists of sandy limestone, marl, sandstone, and chert (Rusmana et al., 1993). Especially in the Tintingon area, it is composed of limestone lithology.

Research Methods

This research requires tools and materials used in the field and the laboratory. Tools and materials in the field include a geological hammer, geological compass, GPS, roll meter, and sample bag. Tools and materials in the laboratory include polarizing microscopes, digital balances, microwaves, desiccators, and rock samples. This research consists of three stages. The first stage is data collection. Data collection was in the form of stratigraphic measurements on representative limestone outcrops. The measurement path starts from the bottom to the top of the outcrop, by measuring the thickness of each layer found. Based on the measured stratigraphic measurements, the overall thickness of the outcrop was 194.66 meters, which was dominated by calcarenite limestone (Figure 2). Rock samples were taken from fresh rock outcrops for further analysis in the laboratory.

Figure 2. The appearance of calcarenite limestone outcrops with the direction of photo N120^{0}E.

The second stage is laboratory analysis. Laboratory analysis consists of two, which are petrographic analysis and porosity analysis. The petrographic analysis aims to determine the microscopic characteristics of the limestone and the pore types in the rock. Petrographic analysis was initiated by making thin sections on 7 rock samples taken from 7 field observation stations with a size of 0.03 mm.

Porosity analysis was carried out on 7 rock samples taken from 7 field observation stations to test the ability of limestone to hold liquid as a groundwater reservoir. Porosity analysis in this study was carried out by measuring in the laboratory. This test begins with preparing a limestone sample which is cut in the shape of a 5x5x5 cm cube. The sample that has been cut is then recorded as the original sample weight value (Wn). After the limestone samples have been weighed, the samples are dried in an oven with a temperature of 800-1000^{0}C for 24 hours, the samples are then cooled in a cooler (desiccator), and each sample is weighed again as a dry sample weight (Wo) and record the value. After weighing the dry sample, the limestone is put into a container filled with water and soaked for 24 hours. After soaking the sample for 24 hours, the sample is weighed and its value is recorded as the saturated sample weight (Ww). After obtaining the saturated sample weight value, pull the rope tied to the sample until the sample position is suspended in the water and record the value as the dependent saturated weight (Ws).

The third stage is data processing and interpretation. This stage includes determining the pore type of rock in thin sections and calculating the porosity of the rock. One of the geologists who classify the pore types of carbonate rocks is Choquette & Pray (1970) (Figure 3). This classification relates the pore size, shape, and packing of the rock.

$$Porosity\ (\%) = \frac{Ww-Wo}{Ww-Ws} x\ 100\% \quad (1)$$

Calculation of rock porosity using equation (1). Where Ww is the weight of the saturated sample after being saturated for 24 hours (grams), Wo is the weight of the dry sample after being baked for 24 hours (grams) and Ws is the weight of the saturated sample depending on water (grams). The results of the porosity calculation are equated with the qualitative classification (Table 1) proposed by Todd (1980).

Table 1. Classification of porosity scale values (Todd, 1980).

Score (%)	Porosity
1 – 10	Large porosity
10 – 20	Medium porosity
20 – 30	Small porosity

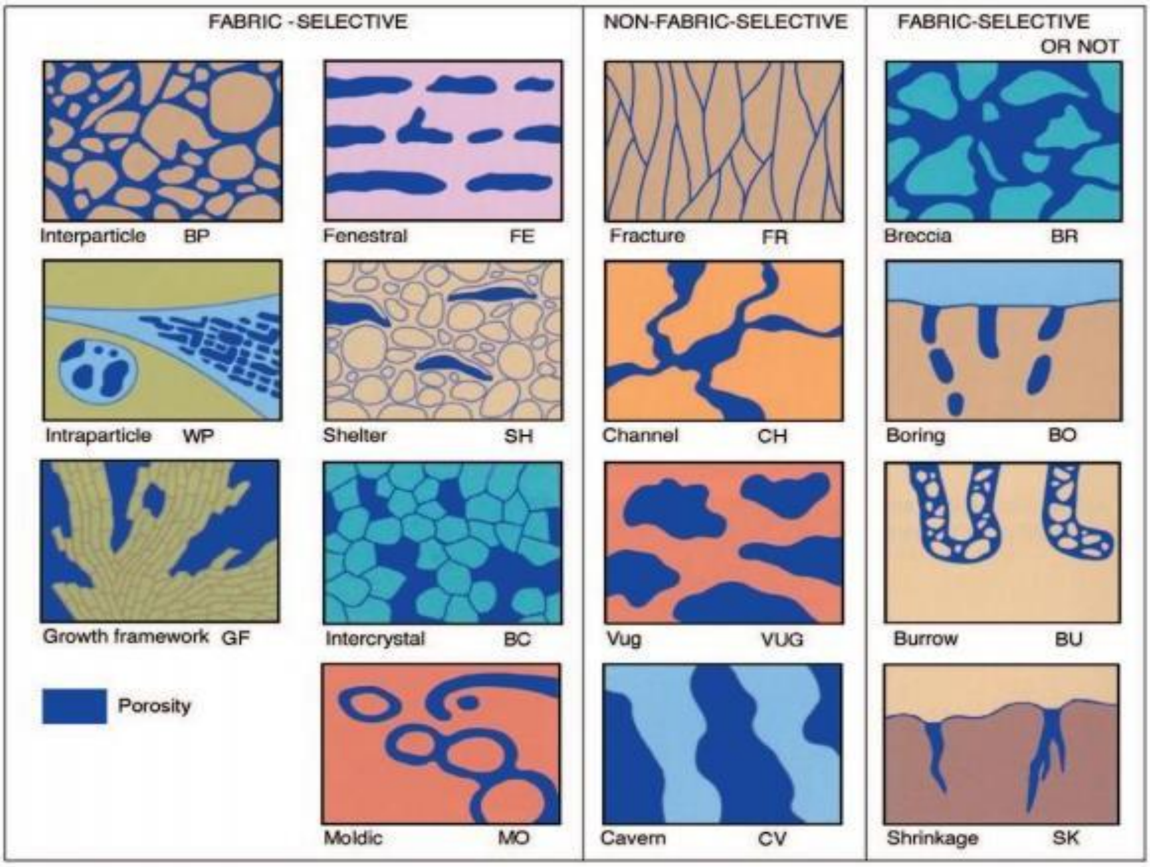

Figure 3. Types of pores in carbonate rocks (Choquette and Pray, 1970).

Results and Discussion

The results and discussion include a description of the lithology and pore types at each station as well as the results of the porosity calculation.

The first station has a fresh white color, gray weathered color, fine to medium grain size (¼-½ mm) with a layer thickness of ±27.75 meters, the grains are circular to very round, there is bioclase in the form of clam shells. Based on thin sections, the rock at this station is packstone (Dunham, 1962) with a pore type, vug (Figure 4.a).

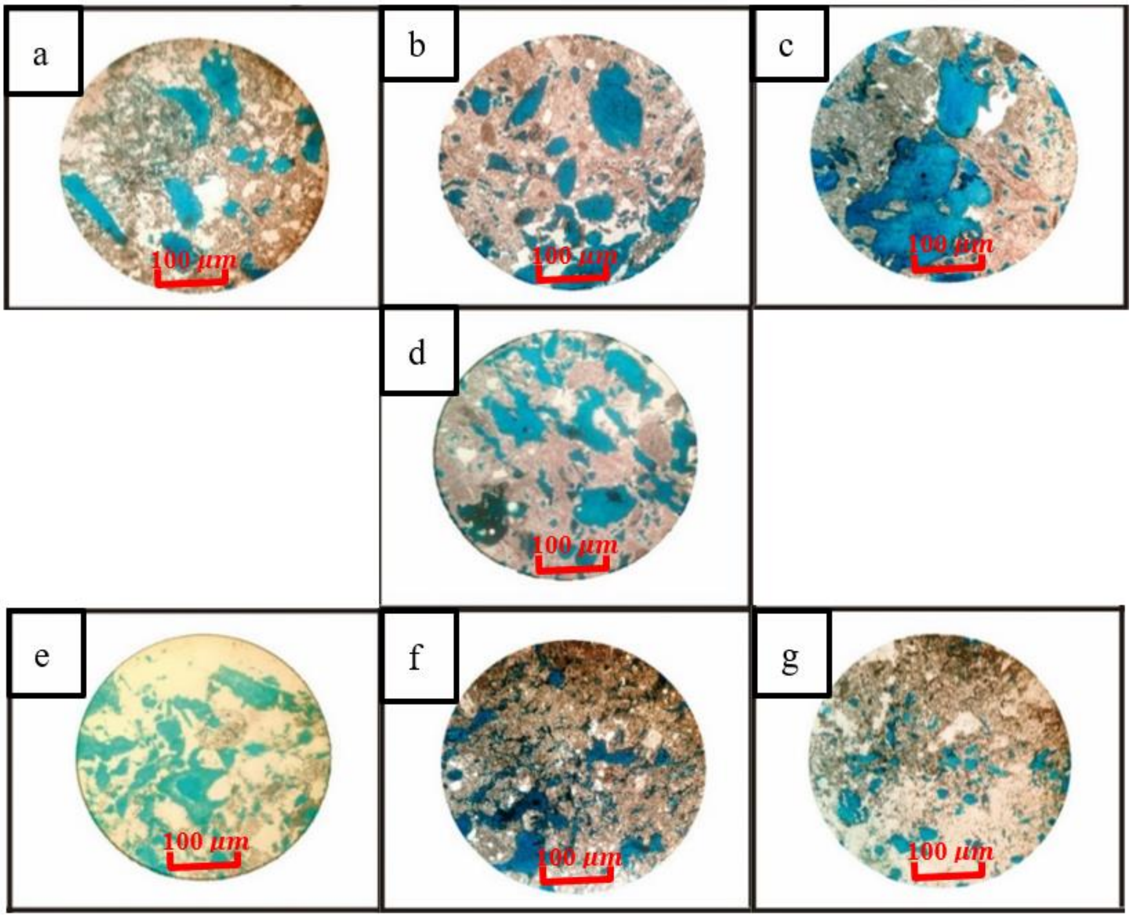

Figure 4. Lithology and pore type of samples in the study area.

The second station has a fresh white color, weathered blackish-gray color, medium to coarse grain size (½-1 mm) with a layer thickness of ±14.70 meters, the grains are semi-round to very round, there are bioclase in the form of shells and fossils macro. Based on thin sections, the rock at this station is wackestone (Dunham, 1962) with a pore type, which is vug (Figure 4.b).

The third station has a fresh grayish-white color, black weathered color, medium to coarse grain size (½-1 mm) with a layer thickness of ±48 meters, granules are half-round to very round, there is bioclase in the form of shells. Based on thin sections, the rock at this station is wackestone (Dunham, 1962) with a pore type in the form of a channel (Figure 4.c).

The fourth station has a fresh white color, grayish-black weathered color, fine to coarse grain size (¼-1 mm) with a layer thickness of ±33.21 meters, the grains are semi-round to very round, there is bioclase in the form of macro fossil shells. Based on thin sections, the rock at this station is wackestone (Dunham, 1962) with a vug pore type (Figure 4.d).

The fifth station has a fresh grayish-white color, weathered gray color, fine to coarse grain size (¼-1 mm) with a layer thickness of ±40.10 meters, granules in the shape of a semi-round to very round shape, there are bioclase in the form of macro fossil shells. Based on thin sections, the rock at this station is wackestone (Dunham, 1962) with a vug pore type (Figure 4.e).

The sixth station has a fresh white color, black weathered color, medium to coarse grain size (½-1 mm) with a layer thickness of ±10 meters, the grains are half-round to very round, there is bioclase in the form of macro-fossil shells. Based on thin sections, the rock at this station is wackestone (Dunham, 1962) with interparticle pore types (Figure 4.f).

The seventh station has a fresh grayish-white color, black weathered color, very fine to fine grain size (1/8-¼mm) with a layer thickness of ±20.90 meters, the grains are in the shape of a semi-round to very round shape. Based on thin sections, the rock at this station is packstone (Dunham, 1962) with an intercrystal pore type (Figure 4.g).

Porosity testing and calculations were carried out on 7 limestone samples from each station. Porosity calculation using equation (1).

Based on the calculation results, the porosity value for each limestone sample is obtained as outlined in Table 2.

Table 2. The results of the porosity calculation are compared with the classification (Todd, 1980).

Station	Parameters Test			Porosity (%)	Todd Classification (1980)
	Wo (gr)	Ww (gr)	Ws (gr)		
1.	295.1	313.9	222.7	20.61	large porosity
2.	320.9	348.7	222.8	22.08	large porosity
3.	387.3	412.0	294.3	20.99	large porosity
4.	233.0	259.3	171.5	29.95	large porosity
5.	248.9	272.2	175.1	24	large porosity
6.	185.8	204.5	116.5	21.25	large porosity
7.	266.0	280.9	183.1	15.24	medium porosity

The results of the porosity calculation above show that samples 1, 2, 3, 5 and 6 have very good porosity. Sample 4 has special porosity and sample 7 has good porosity. The porosity value of the limestone in the study area is 15.24 – 29.95%. Based on this, the limestone in the study area is very good as a groundwater reservoir rock where the greater the porosity of the rock, the greater the amount of water that can be stored in the rock. The presence of water or fluid in the reservoir rock is inseparable from the source rock.

Calculation of the porosity of the limestone in the study area shows the same value as the porosity of the limestone in the city of Gorontalo, which is in the very good category with a porosity of 20–25% (Permana & Eraku, 2020).

Conclusion

Based on the results of laboratory analysis, it can be concluded that the lithology of the limestone in the study area is wackestone and packstone with vug, channel, interparticle and intercrystal pore types. Limestone porosity is 15.24 – 29.95%. The porosity value is in the medium to large category so that the research area is very good as a groundwater reservoir rock.

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Author Contribution

This paper was completed thanks to the collaboration of all the authors. The idea on this topic was first proposed by Nurhikmah Supardi. Most of the data analysis was done by Nurhikmah Supardi. Meltini Pakiding was in charge as completing laboratory testing and Syarifullah Bundang helped arrange the background and some editing. Hopefully this kind of collaboration will continue.

Conflict of Interest

This research was conducted independently without any financial support from any parties.

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