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# Valuation of Physical Properties of Rocks in the Maros Pangkep Karst Area of Bantimurung Bulusaraung National Park

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**Abstract:** This research is an experimental study that aims to analyze and valuate the physical properties of rocks in the Maros Pangkep Karst Area. The samples were 60 (sixty) consisted of each 30 (thirty) samples in the Maros Karst Area (04°58'-05°01' S and 119°39'-119°41' E) and in the Pangkep Karst Area (04°51'-04°53' S and 119°37'-119°38' E). The analysis results of the physical properties of rocks in the Maros Karst Area obtained modified limestone and dolomite limestone with density values in the range of 1.50-2.68 g/cm³ and porosity of 0-50%, indicating secondary porosity. The Pangkep Karst Area obtained dolomite limestone with density values of 2.47-2.65 g/cm³ and porosity of 0-5%, indicating primary porosity. There are differences in physical properties of rock in the Maros Karst Area and Pangkep Karst Area based on an independent sample t-test. The valuation of the physical properties of rocks in the Maros Karst Area have special quality (5-50%), sufficient quality (10-15%), poor quality (5-10%), and negligible quality (0-5%) and in the Pangkep Karst Area has negligible quality (0-5%). Based on this valuation, karst rocks in the Maros Karst Area can be recommended reservoar and karst rocks in the Pangkep Karst Area can be recommended as aggregate limestone.

**Keywords:** Physical Properties; Porosity; Density; Valuation; Karst

## Introduction

The Maros Pangkep Karst Area (MPKA) is one of the karst areas in South Sulawesi Province and is the largest karst area after the China Karst Region. The geological history of the growth of the MPKA hills begins in the Late Eocene to Middle Miocene (40 million to 15 million years ago) which is the Tonasa Formation (Ahmad, 2011). The tectonic process of uplift exceeding the speed of the dissolution process predominantly becomes vertical, thus forming a karst topography (Husein et al., 2008). Geological processes and dissolution have formed a unique expanse of geological diversity in the form of limestone outcrops, karst caves, stalactites, stalagmites, and springs (BPS, 2020).

MPKA is a unitary karst area which is basically a stretch of karst hills, extending from south to north. MPKA has an area of 43,750 ha which is spread over two regencies, namely Maros Regency and Pangkep Regency (Fatinaware et al., 2019). MPKA, which is a unitary karst area, is divided into two parts by the existence of government policies in determining regional administrative boundaries, namely the Maros Karst Area in Maros Regency and the Pangkep Karst Area in Pangkep Regency (Ahmad and Hamzah, 2016).

In carbonate rocks that mostly form karst areas, fractures are very dominant because these rocks are relatively more brittle than other rocks in the area. Karst that develops is often found in carbonate rocks (Arsyad, 2002). Rocks with soluble properties are one of the factors in the development of karstification. In addition, environmental factors also affect the karstification process, such as climate. Climate is a factor that influences the development of karst. The most important climatic factor in the development of karst is rainwater (Haryono and Adji, 2010).

The Maros Karst Area and the Pangkep Karst Area have almost the same climatic conditions, namely

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rainfall type C (slightly wet) with almost the same wet month characteristics. Based on the analysis results obtained, the Maros Karst Area has six wet months from November-April (Arham et al., 2015). The Pangkep Karst Area also has six wet months from November-April (Upa et al., 1990).

Climate as an active factor in weathering that can affect the physical and mechanical conditions of rocks in karst areas (Tamanak et al., 2020). In addition to climatic factors, there are other factors that can affect the physical and mechanical properties. (Rosari et al., 2017) examined the physical and mechanical properties of karst rocks in Maros to analyze the density, porosity, and compressive strength values of rocks. From the results of his research, obtained a density value of 2-3 g/cm³ . The value of rock porosity was obtained on a scale of 0-5% with dolomite rock types and 5-50% scale with karstified limestone types. The compressive strength test values obtained were 20.87 MPa, 23.69 MPa, and 33.70 MPa.

In line with that (Arsyad et al., 2020), researched the physical and mechanical properties of rocks in the Pangkep area. The density value of rocks obtained are 2.2-2.7 g/cm ³ and the rock porosity values are on a scale of 0-5% and 5-50% with the rock types being dolomite and karstified limestone. The value of the compressive strength of rocks shows that both types of rock have weak strength qualities of 5-25 MPa and moderate quality of 25-50 MPa.

This research is a continuation of previous research by examining differences in the physical properties of rocks in the Maros Karst Area and the Pangkep Karst Area. In this study, a limitation was given, namely only on testing the physical properties of rocks, so that testing of mechanical properties was not carried out in this study. Based on the data on the physical properties of the rocks obtained, it can be evaluated (assessment) in the form of rock quality and then it can be used as a reservoar or in the field of development.

The feasibility of limestone to be used in construction can be reviewed based on its physical and mechanical properties. The physical properties of rocks have a significant influence on their mechanical properties (Ariyanto et al., 2020). Physical properties of karst rocks are properties that can be observed and calculated on karst rocks before being given a force or pressure without changing the chemical composition of the rock. Rock physical properties consist of density and porosity. Mathematically the density can be written as follows.

$$\rho = \frac{m}{V} \tag{1}$$

with ρ is the rock density in units of g/cm³ or kg/m³, m is the rock mass in grams (g) or kilograms (kg), and V is the volume of the whole rock in milliliters (ml) or cm³ .

Each type of rock has a range of different density values. Based on the theory of Telford (1990), limestone has a density value range of 1.93-2.90 g/cm³ and dolomite 2.28-2.90 g/cm³.

Density applications can be used in several aspects such as determining the physical properties of other rocks, namely natural density, dry density, and saturated density. Natural density is the ratio between the weight of the original rock and the total volume of rock. Dry density is the ratio between the weight of dry rock with the total volume of rock. Saturated density is the ratio of the mass of rock in a saturated state to the total volume of rock.

Porosity is the ability to absorb fluids in rock. Porosity can be expressed as a ratio between the volume of voids in the rock and the total volume of the rock and is expressed in percent. Mathematically it can be written as follows.

$$n = \frac{W_w - W_o}{W_w - W_s} \tag{2}$$

n is the porosity expressed in % (percent) where $W_o$ is the dry weight, $W_w$ is the saturated weight, and $W_s$ is the weight of the sample suspended in water.

Determination of rock porosity is based on theory (Haryono & Adji, 2010). Limestone and dolomite rock that has not been karstified have a very small range of porosity values (0-5%) and if karstified will have a high porosity value (5-50%). Porosity develops in karst hills which occurs due to a secondary process in the form of dissolving limestone which eventually forms a cavity in the form of a cave passage (protocave) (Munawir et al., 2019). Porosity can be a determinant of whether or not a rock is a reservoir. The determination can be reviewed based on the quality scale of whether or not the porosity value by Koesoemadinata (Koesoemadinata, 1978).

## Method

This research is experimental research which that includes testing the physical properties (density and porosity) of rocks. Rock samples were taken in the Maros Karst Area and Pangkep Karst Area which were spread over 4 (four) locations, namely Location I representing Leang-Leang (04°58'-05°00' S and 119°39'-119°40' E), Location II represents Bantimurung (05°00'-05°01' S and 119°39'-119°41' E), Location III represents Leang Londrong (04°51'-04°52' S and 119°37' - 119°38 E), and Location IV represents a former resident mine (04°52'-04°53' S and 119°37' E). The number of sampling points is 60 (sixty) points spread over 20 (twenty) points at Location I, 10 (ten) points at Location II, 21 (twenty-one) points at Location III, and 9 (nine) points at Location IV.

The distribution of sampling points can be seen in Figure 1 for the Maros Karst Area (Location I and Location II).

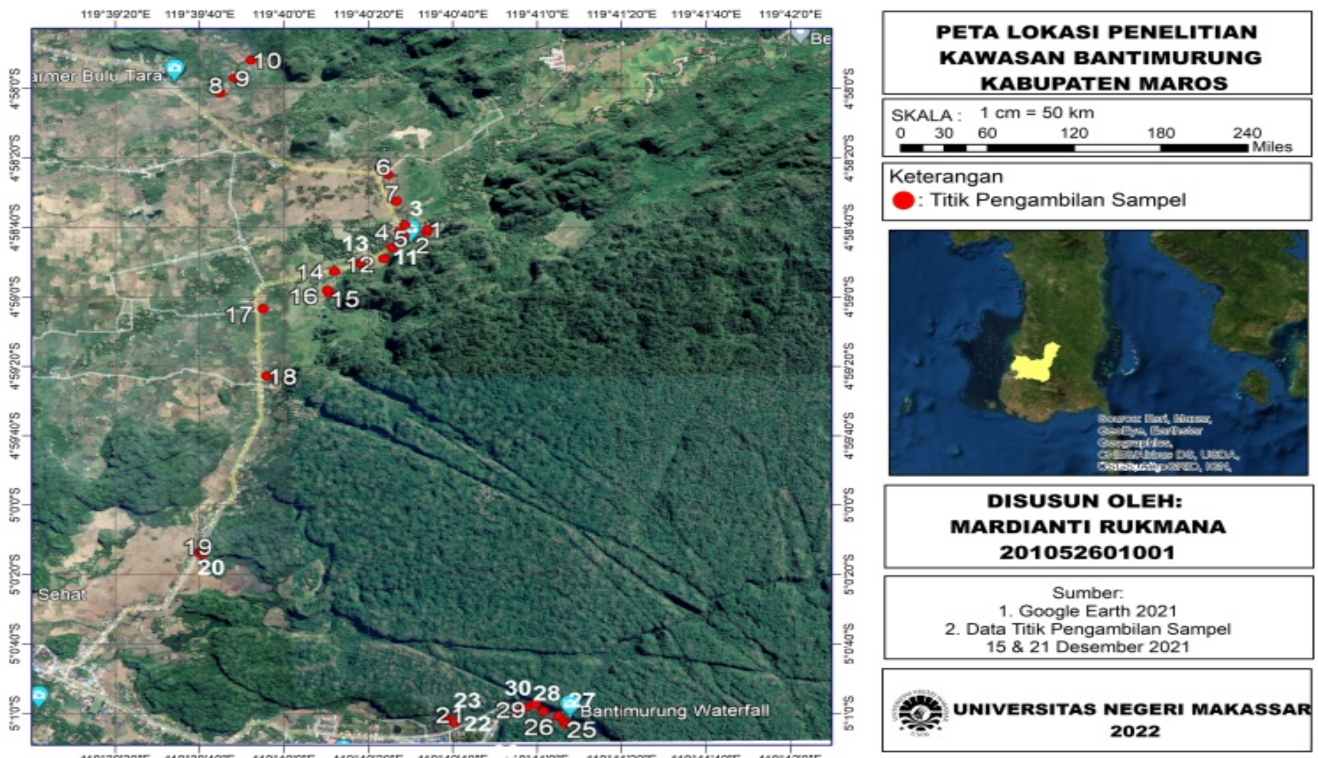


**Figure 1.** Map of Location of Sampling Points for Maros Karst Area

The distribution of sampling points can be seen in Figure 2 for the Pangkep Karst Area (Location III and Location IV).

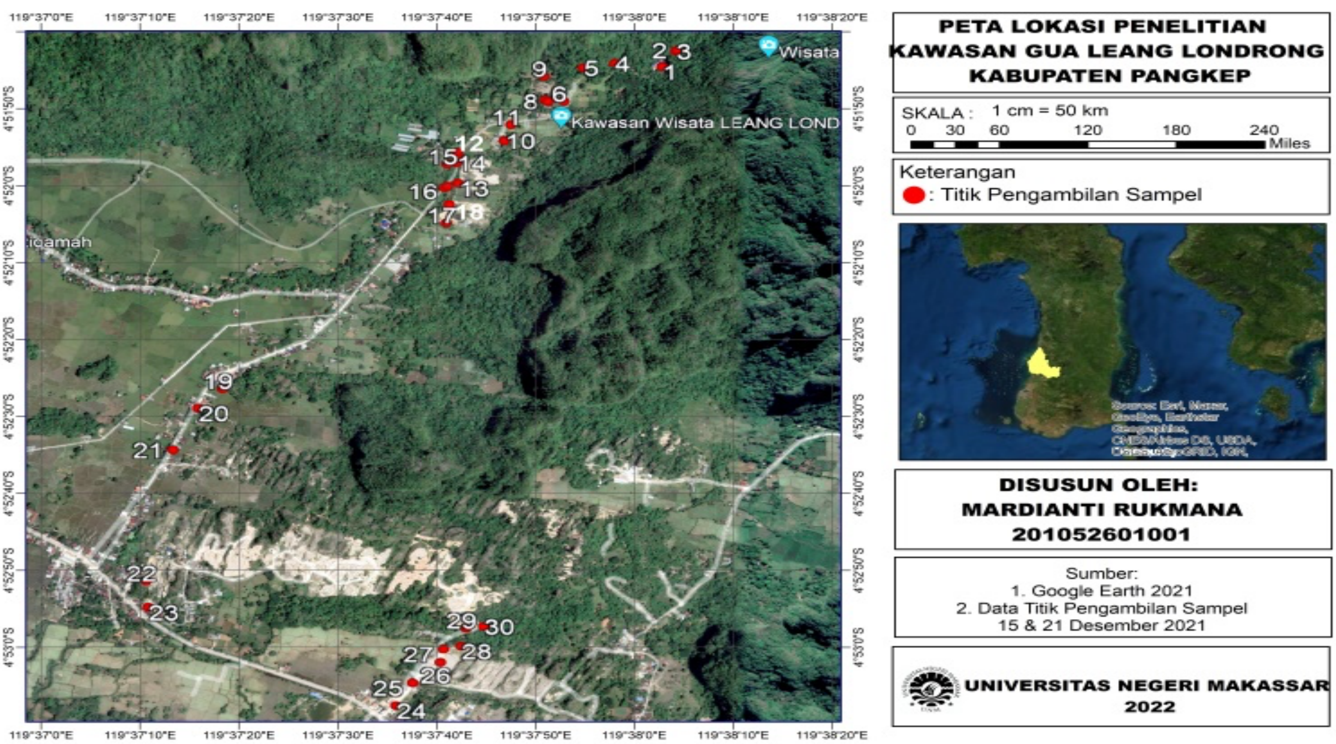


**Figure 2.** Location Map of Pangkep Karst Area Sampling Points

The rock samples obtained were then prepared into a 5 cm cube shape. Physical properties testing was carried out using the gravity method according to the standard testing procedure by SNI 03-1969-1990 by measuring the rock mass such as the weight of the original sample, the weight of the dry sample, the weight of the saturated sample, and the weight of the sample depending on water. These quantities are used to obtain rock physical properties such as density and porosity using equations (1) and (2).

The density and porosity values obtained in the two karst areas were compared by performing a difference t-test. For testing, the data must be normally distributed and there are no outliers. If there are outliers, then there are several options, such as case deletion (Field, 2009). The normality test was carried out using the Liliefors ($L_o$) test using equation (3) and the difference t-test using equation (4). Statistical tests were carried out using the SPSS program.

$$z_i = \frac{x_i - \bar{x}}{S} \quad (3)$$

Description: $z_i$ = standard number to i
$x_i$ = research data to i
$\bar{x}$ = average value
S = standard deviation

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{SS_1 + SS_2}{n_1 + n_2 - 2}\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} \quad (4)$$

Description: $\bar{x}_1$ = group mean score 1
$\bar{x}_1$ = group mean score 2
$SS_1$ = sum of square group 1
$SS_2$ = sum of square group 2
$n_1$ = number of data group 1
$n_2$ = number of data groups 2

The hypothesis proposed in this study is as follows.
$H_0$ : There is no difference in the physical properties of rocks in the Maros Karst Area and the Pangkep Karst Area
$H_1$ : There are differences in the physical properties of rocks in the Maros Karst Area and the Pangkep Karst Area

The determination of $H_0$ is accepted or rejected, that is, if the T-test statistic > $T_{table}$, then $H_0$ is rejected and $H_1$ is accepted or if sig (two tailed) < 0.05, then $H_0$ is rejected and $H_1$ is accepted (Nuryadi et al., 2017). The valuation is carried out based on the quality standard of rock porosity by Koesoemadinata (1978).

The tools used in this research are 1) geological hammer; 2) Global Position System (GPS); 3) Meters; 4) Camera; 5) Grinding machine and dry stone cutting grinding wheel; 6) caliper; 7) Digital balance with accuracy 0.01 g; 8) Oven Memmert; 9) Container; 10) Vessel; 11) Stative clamps; 12) Hanging device; 13) Duster. The materials used are 1) rock samples (cube 5 cm); 2) water. The steps taken in this study can be seen in Figure 3.

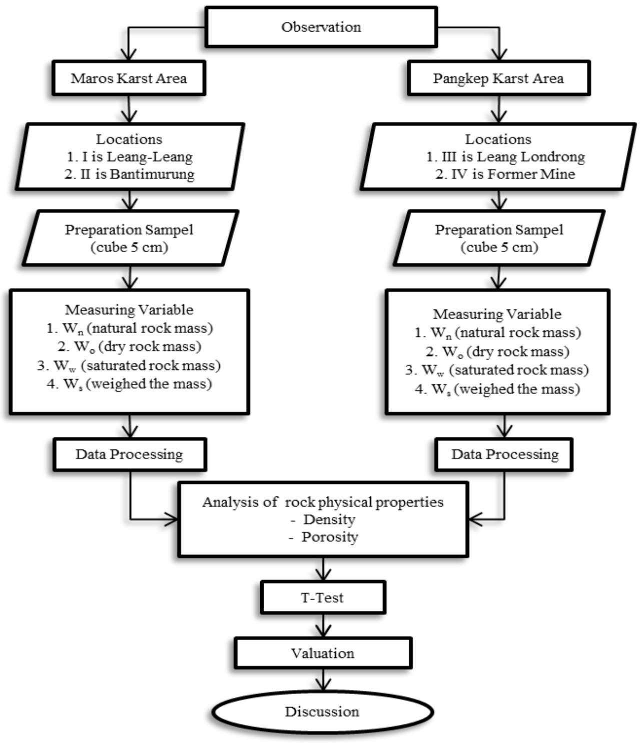


**Figure 3.** Research flow chart

## Result and Discussion

*Physical Properties of Rocks in the Maros Karst Area and Pangkep Karst Area*

Testing of rock physical properties is carried out to obtain rock density and porosity values. The results of the analysis of the physical properties of rocks in the Maros Karst Area can be seen in Table 1.

Based on Table 1, various rock density values were obtained. Rocks in the Maros Karst Region have density ($\rho$) values 1.50-2.68 g/cm$^3$ indicates that the rock type in the Maros Karst Area is limestone. The density values at Location I are in the range of 1.50 -2.68 g/cm$^3$ and at Location II are in the range of 2.23–2.54 g/cm$^3$.

Rock density can be affected by several factors such as rock porosity. The results showed that the greater the rock porosity, the smaller the rock density value. This is in line with research (Melati, 2019). The more water that is able to be absorbed by the rock, it indicates that the rock has a large porosity. If more water enters the rock, the rock density will decrease.

Based on Table 1, the varying rock porosity (n) values are obtained, in the range of 0-50% (Location I and Location II). For the determination of the type of material, based on the theory of rock porosity by Haryono & Adji (2010). The data obtained indicate that there are 9 (nine) samples that have porosity values above 5% indicated dolomite limestone and 21 (twenty-one) samples have porosity values below 5% indicated modified limestone. Based on the data obtained, it shows that the type of porosity in the Maros Karst Region is secondary porosity.

**Table 1:** Results of Analysis of Physical Properties of Rocks in the Karst Maros Area

| Loc | Sample | $\rho$ (g/cm$^3$) | n (%) | Rock Type |
|---|---|---|---|---|
| I | $M_1$ | 1.50 | 43.71 | Modified limestone |
| | $M_2$ | 2.53 | 2.01 | Dolomite limestone |
| | $M_3$ | 2.57 | 3.25 | Dolomite limestone |
| | $M_4$ | 2.61 | 1.27 | Dolomite limestone |
| | $M_5$ | 2.66 | 0.54 | Dolomite limestone |
| | $M_6$ | 2.35 | 9.25 | Modified limestone |
| | $M_7$ | 2.62 | 1.43 | Dolomite limestone |
| | $M_8$ | 2.55 | 2.70 | Dolomite limestone |
| | $M_9$ | 2.64 | 0.72 | Dolomite limestone |
| | $M_{10}$ | 2.68 | 0.16 | Dolomite limestone |
| | $M_{11}$ | 2.60 | 2.13 | Dolomite limestone |
| | $M_{12}$ | 2.64 | 0.93 | Dolomite limestone |
| | $M_{13}$ | 2.66 | 0.39 | Dolomite limestone |
| | $M_{14}$ | 2.66 | 0.23 | Dolomite limestone |
| | $M_{15}$ | 2.53 | 3.63 | Dolomite limestone |
| | $M_{16}$ | 2.39 | 6.83 | Modified limestone |
| | $M_{17}$ | 2.39 | 7.21 | Modified limestone |
| | $M_{18}$ | 2.41 | 6.42 | Modified limestone |
| | $M_{19}$ | 2.64 | 0.46 | Dolomite limestone |
| | $M_{20}$ | 2.67 | 0.20 | Dolomite limestone |
| Value Range | | 1.50-2.68 | 0.16-43.71 | |
| II | $M_{21}$ | 2.49 | 0.20 | Dolomite limestone |
| | $M_{22}$ | 2.46 | 3.35 | Dolomite limestone |
| | $M_{23}$ | 2.47 | 4.37 | Dolomite limestone |
| | $M_{24}$ | 2.34 | 3.75 | Dolomite limestone |
| | $M_{25}$ | 2.54 | 8.35 | Modified limestone |
| | $M_{26}$ | 2.48 | 3.74 | Dolomite limestone |
| | $M_{27}$ | 2.56 | 5.17 | Modified limestone |
| | $M_{28}$ | 2.40 | 2.18 | Dolomite limestone |
| | $M_{29}$ | 2.23 | 6.95 | Modified limestone |
| | $M_{30}$ | 2.46 | 13.12 | Modified limestone |
| Value Range | | 2.23-2.56 | 0.20-13.12 | |
| Maros Karst Area | | 1.50-2.68 | 0.16-43.71 | |

In this study, the density values obtained were in the range of 1.50-2.68 g/cm$^3$ which indicated that the rock type was limestone and in previous studies, (Rosari et al., 2017) the values ranged from 2.72 to 3.31 g/cm$^3$ which is a type of limestone. The porosity value obtained also shows a value that is almost the same as the previous study, which is in the 0-50% scale range, which consists of unkarstified and karstified limestone.

Based on this, the physical properties of rocks in the Maros Karst Area can be influenced by internal factors such as geological conditions due to the uplifting process that occurred from the Late Eocene to Middle Miocene. In addition, karstified limestone also shows that not only geological factors, but there are other factors that affect rock porosity, namely external factors such as climatic conditions where rocks exist and the dissolving process that occurs. The rock-forming porosity is dominantly influenced by the results of the dissolution process that occurs in limestone because it is easily soluble in water, so it is very possible to form cavities, channels, and underground caves. The dissolving process that occurs has caused the porosity of the rock to become large. Sufficient rainfall >250 to be a factor karstification can take place until now.

The Maros Karst Area and the Pangkep Karst Area are a single karst area, but due to administrative boundaries, the karst area is divided into the Maros Karst Area in Maros Regency and the Pangkep Karst Area in Pangkep Regency. The existence of different locations can affect the physical properties of rocks because the climatic conditions in the two districts are almost the same but slightly different. The results of the analysis of the physical properties of rocks in the Pangkep Karst Area at Location III representing Leang Londrong and Location IV representing former resident mines can be seen in Table 2.

**Table 2:** Analysis of Physical Properties of Rocks in the Pangkep Karst Area

| Loc | Sample | $\rho$ (g/cm$^3$) | n (%) | Rock Type |
|---|---|---|---|---|
| III | $P_1$ | 2.63 | 1.19 | Dolomite limestone |
| | $P_2$ | 2.58 | 0.68 | Dolomite limestone |
| | $P_3$ | 2.50 | 2.64 | Dolomite limestone |
| | $P_4$ | 2.54 | 3.61 | Dolomite limestone |
| | $P_5$ | 2.58 | 2.24 | Dolomite limestone |
| | $P_6$ | 2.54 | 3.35 | Dolomite limestone |
| | $P_7$ | 2.58 | 2.27 | Dolomite limestone |
| | $P_8$ | 2.60 | 2.30 | Dolomite limestone |
| | $P_9$ | 2.53 | 3.93 | Dolomite limestone |
| | $P_{10}$ | 2.61 | 1.24 | Dolomite limestone |
| | $P_{11}$ | 2.64 | 0.76 | Dolomite limestone |
| | $P_{12}$ | 2.59 | 1.63 | Dolomite limestone |
| | $P_{13}$ | 2.62 | 1.07 | Dolomite limestone |
| | $P_{14}$ | 2.61 | 1.95 | Dolomite limestone |
| | $P_{15}$ | 2.60 | 1.66 | Dolomite limestone |
| | $P_{16}$ | 2.63 | 1.20 | Dolomite limestone |
| | $P_{17}$ | 2.64 | 0.60 | Dolomite limestone |
| | $P_{18}$ | 2.59 | 1.42 | Dolomite limestone |
| | $P_{19}$ | 2.55 | 3.09 | Dolomite limestone |
| | $P_{20}$ | 2.47 | 3.94 | Dolomite limestone |
| | $P_{21}$ | 2.54 | 2.69 | Dolomite limestone |
| Value Range | | 2.47-2.64 | 0.60-3.94 | |
| IV | $P_{22}$ | 2.63 | 0.81 | Dolomite limestone |
| | $P_{23}$ | 2.63 | 0.83 | Dolomite limestone |
| | $P_{24}$ | 2.59 | 1.39 | Dolomite limestone |
| | $P_{25}$ | 2.59 | 2.54 | Dolomite limestone |
| | $P_{26}$ | 2.57 | 1.93 | Dolomite limestone |
| | $P_{27}$ | 2.61 | 1.22 | Dolomite limestone |
| | $P_{28}$ | 2.63 | 0.85 | Dolomite limestone |
| | $P_{29}$ | 2.65 | 0.88 | Dolomite limestone |
| | $P_{30}$ | 2.64 | 1.24 | Dolomite limestone |
| Value Range | | 2.57-2.65 | 0.81-2.54 | |
| Pangkep Karst Area | | 2.47-2.65 | 0.60-3.94 | |

Based on Table 2, various density ($\rho$) values are obtained for Location III IV. The rock density values at Location III are in the range of 2.47-2.64 g/cm³ and Location IV the density values obtained are in the range 2.57-2.65 g/cm³. The porosity value obtained also varies with a value range of 0.60 -3.94 %. In general, the density values obtained in the Pangkep Karst Area are in the range of 2.47-2.65 g/cm³.

Rocks in the Pangkep Karst Area have a low porosity (n) value in the 0-5% range. Based on the porosity data, it can be seen the type of rock and the type of material. The type of rock in the Pangkep Karst Area is limestone and is a type of dolomite material. Limestone from the Pangkep Karst Area is dominated by dolomite with a very small porosity scale. The dominant dolomite material in the Pangkep Karst Area indicates that the type of porosity in the Pangkep Karst Area is primary. The formation of porosity in rocks is influenced by internal factors such as geological conditions due to the uplifting process that occurred from the Late Eocene to Middle Miocene (40 to 15 million years ago).

The results of the analysis of rock density and porosity in the Pangkep Karst Area obtained in this study are different from the results of previous studies by (Arsyad et al., 2020). The difference lies in the porosity value obtained. The porosity value in this study is on a scale of 0-5% with the type of material obtained is dolomite, while in previous studies the porosity value obtained is on a scale of 0-50% with the type of material being karstified limestone and dolomite. The type of porosity in the previous study was secondary porosity because there was a porosity that had a scale of 5-50%, but in this study the porosity value obtained was only on a scale of 0-5% with the type of porosity being primary porosity.

Based on the data of physical properties that have been obtained, it can be estimated rock age. Dolomite limestone is the original limestone originating from karst hills formed 40 to 15 million years ago. Due to external factors where rocks exist, such as climatic conditions and the dissolving process that occurs, the rocks are karsified so that the dolomite limestone becomes karstified limestone which is characterized by its high porosity value as in the $M_1$ rock sample. Sufficient rainfall as a karstification factor is still ongoing today.

Dolomite in the Maros Karst Area can be found on karst hills due to the ambient air temperature. Dolomite limestone with a large density and small porosity is the cause of the appearance of towering karst hills in the Maros Karst Region that can still exist today. The karstified limestone obtained in the Maros Karst Area is only located at the foot of the hill. This shows that modified limestone is a younger limestone than dolomite limestone because it is formed from the dissolving process. In addition, it can be indicated that the limestone in the Pangkep Karst Area is the original limestone and has an older age than the limestone found in the Maros Karst Area.

*Differences in the Physical Properties of Rocks in the Maros Karst Area and the Pangkep Karst Area*

The difference test was carried out with a difference t-test (Independent Sample T-Test) using the SPSS program. The requirements for the Independent Sample T-Test are that the data is normally distributed and there are two independent variables. To test whether the data has a normal distribution or not, a normality test can be performed using Lillifors significance. The amount of data used is 29 because there is one data that is outliers. The results of the normality test can be seen in Table 3 as follows (significance value 0.05 and $L_{table}$ 0.161).

**Table 3.** Normality Test Results of Rock Physical Properties in the Karst Area of Maros Pangkep

| Parameter | Karst | N | $L_{value}$ | Sig. | Description |
|---|---|---|---|---|---|
| Natural | Maros | 29 | 0.114 | 0.200 | Normal |
| density | Pangkep | 29 | 0.133 | 0.200 | Normal |
| Dry | Maros | 29 | 0.117 | 0.200 | Normal |
| density | Pangkep | 29 | 0.132 | 0.200 | Normal |
| Saturated | Maros | 29 | 0.132 | 0.200 | Normal |
| density | Pangkep | 29 | 0.133 | 0.200 | Normal |
| Porosity | Maros | 29 | 0.143 | 0.132 | Normal |

Based on Table 3, obtained a significance value of 0.200 > 0.05 and $L_{value} < L_{table}$ , namely 0.114 < 0.161 for the Maros karst and 0.133 < 0.161 for the Pangkep karst. Therefore, the data for the natural density parameter in the Maros and Pangkep Karst Regions are normally distributed. Dry density parameter data shows a significance value > 0.05, and the $L_{value} < L_{table}$ is 0.117 < 0.161 for the Maros karst and 0.132 < 0.161 for the Pangkep karst. The significance value is 0.200 > 0.05 for the saturated bulk density of rock in the Maros karst and Pangkep karst, so that the saturated rock density data is normally distributed with $L_{value} < L_{table}$ , namely 0.132 < 0.161 and 0.133 < 0.161.

Based on Table 3, the normality test results for rock porosity are obtained with a significance value of 0.132 > 0.05 for Maros karst and a calculated $L_{value}$ of 0.143 < $L_{table}$ (0.161), so that the rock porosity data in the Maros Karst Area is normally distributed and for rock porosity in the karst. Pangkep, obtained a significance value of 0.053 > 0.05 and the value of $L_{value} = L_{table}$ (0.161 = 0.161). This means that rock porosity data in the Pangkep Karst Area is normally distributed. Therefore, the prerequisite test is met and then a t-test is carried out, namely the Independent Sample T-Test.

Hypothesis testing uses independent sample t-test analysis with reference, if the significance value is < 0.05, then $H_0$ is rejected and $H_1$ is accepted and if the $T_{value} > T_{table}$, then $H_0$ is rejected and $H_1$ is accepted. The following are the results of the Independent Sample T-Test which are presented in Table 4 (significance value 0.05).

**Table 4.** Test Results of Independent Sample T-test Parameters of Physical Characteristics of Rocks in the Karst Area of Maros Pangkep

| Parameter | Karst | N | Mean | Mean difference | Tvalue | Sig.(2- tailed) |
|---|---|---|---|---|---|---|
| Natural density | Maros | 29 | 2.5252 | 0.06897 | 2.965 | 0.00 |
| | Pangkep | 29 | 2.5941 | | | |
| Dry density | Maros | 29 | 2.5245 | 0.0614 | 2.778 | 0.009 |
| | Pangkep | 29 | 2.5886 | | | |
| Saturated density | Maros | 29 | 2.5600 | 0.04690 | 2.727 | 0.010 |
| | Pangkep | 29 | 2.6069 | | | |
| Porosity | Maros | 29 | 3.6548 | 1.88655 | 3.030 | 0.005 |
| | Pangkep | 29 | 1.7655 | | | |

Based on Table 4, the interpretation of the t test shows that the probability value based on the Asymp.Sig (2-tailed) value is 0.006 for the original content weight parameter. The significance value < 0.05 and the $T_{value}$ obtained shows a value of 2.965 > $T_{table}$ that is 2.03224 (df = 34), so $H_0$ is rejected and $H_1$ is accepted. This means that there is a difference in the average value of the original rock mass in the Maros Karst Area and the Pangkep Karst Area with a value of 0.06897.

Based on Table 4, the interpretation of the t test shows that the probability value based on the Asymp.Sig (2-tailed) value is 0.009 for the dry weight parameter. The significance value < 0.05 and the $T_{value}$ obtained shows a value of 2.778 > $T_{table}$ which is 2.03452 (df = 33), so $H_0$ is rejected and $H_1$ is accepted. This means that there is a difference in the average dry weight of rock in the Maros Karst Area and the Pangkep Karst Area of 0.06414.

Based on Table 4, the interpretation of the t test shows that the probability value based on the Asymp.Sig (2-tailed) value for the saturated rock density is 0.010 < 0.05 and $T_{value}$ obtained shows a value of 2.727 > $T_{table}$ which is 2.03244 (df = 34), so that $H_0$ is rejected and $H_1$ is accepted. This means that there is a difference in the average saturation weight of rocks in the Maros Karst Area and the Pangkep Karst Area of 0.04690.

Based on Table 4, the interpretation of the t test shows that the probability value based on the Asymp.Sig (2-tailed) value for porosity is 0.005 < 0.05 and the calculated $T_{value}$ obtained shows the $T_{value}$ > $T_{table}$ (3.030 > 2.03452), so $H_0$ is rejected and $H_1$ is accepted. This means that there is a difference in the average value of rock porosity in the Maros Karst Area and the Pangkep Karst Area of 1.88931.

Based on the difference tests that have been carried out, it can be seen that there are differences in the physical properties of rocks in the Maros Karst Area and the Pangkep Karst Area. Internal factors such as the influence of geology and external factors in the form of dissolution and climatic conditions of the presence of rocks are thought to be the factors causing the differences in the physical properties of rocks in the two karst areas.

*Valuation of Physical Properties of Rocks in the Maros Karst Area and Pangkep. Karst Area*

Valuation is an assessment method carried out on existing Natural Resources (SDA). In this study, the valuation carried out is an assessment of the quality of limestone in the Maros Pangkep Karst Area based on data on the physical properties of rocks in the Maros Karst Area and Pangkep Karst Area. The grading standard is based on a visual porosity scale assessment by assessing rock quality by Koesoemadinata.

Based on the data on physical properties that have been obtained in Table 1 and Table 2, it is possible to evaluate the rock quality as shown in Table 5.

**Table 5.** Valuation of Physical Properties of Rocks in the Karst Area of Maros Pangkep

| Loc | Sample | n scale | Quality | Loc | Sample | n scale | Quality |
|---|---|---|---|---|---|---|---|
| I | $M_1$ | 5-50 | Excellent | II | $P_1$ | 0-5 | Negligible |
| | $M_2$ | 0-5 | Negligible | | $P_2$ | 0-5 | Negligible |
| | $M_3$ | 0-5 | Negligible | | $P_3$ | 0-5 | Negligible |
| | $M_4$ | 0-5 | Negligible | | $P_4$ | 0-5 | Negligible |
| | $M_5$ | 0-5 | Negligible | | $P_5$ | 0-5 | Negligible |
| | $M_6$ | 5-10 | Poor | | $P_6$ | 0-5 | Negligible |
| | $M_7$ | 0-5 | Negligible | | $P_7$ | 0-5 | Negligible |
| | $M_8$ | 0-5 | Negligible | | $P_8$ | 0-5 | Negligible |
| | $M_9$ | 0-5 | Negligible | | $P_9$ | 0-5 | Negligible |
| | $M_{10}$ | 0-5 | Negligible | | $P_{10}$ | 0-5 | Negligible |
| | $M_{11}$ | 0-5 | Negligible | | $P_{11}$ | 0-5 | Negligible |
| | $M_{12}$ | 0-5 | Negligible | | $P_{12}$ | 0-5 | Negligible |

| Loc | Sample | n scale | Quality | Loc | Sample | n scale | Quality |
|---|---|---|---|---|---|---|---|
| | $M_{13}$ | 0-5 | Negligible | | $P_{13}$ | 0-5 | Negligible |
| | $M_{14}$ | 0-5 | Negligible | | $P_{14}$ | 0-5 | Negligible |
| | $M_{15}$ | 0-5 | Negligible | | $P_{15}$ | 0-5 | Negligible |
| | $M_{16}$ | 5-10 | Poor | | $P_{16}$ | 0-5 | Negligible |
| | $M_{17}$ | 5-10 | Poor | | $P_{17}$ | 0-5 | Negligible |
| | $M_{18}$ | 5-10 | Poor | | $P_{18}$ | 0-5 | Negligible |
| | $M_{19}$ | 0-5 | Negligible | | $P_{19}$ | 0-5 | Negligible |
| | $M_{20}$ | 0-5 | Negligible | | $P_{20}$ | 0-5 | Negligible |
| II | $M_{21}$ | 0-5 | Negligible | | $P_{21}$ | 0-5 | Negligible |
| | $M_{22}$ | 0-5 | Negligible | IV | $P_{22}$ | 0-5 | Negligible |
| | $M_{23}$ | 0-5 | Negligible | | $P_{23}$ | 0-5 | Negligible |
| | $M_{24}$ | 0-5 | Negligible | | $P_{24}$ | 0-5 | Negligible |
| | $M_{25}$ | 5-10 | Poor | | $P_{25}$ | 0-5 | Negligible |
| | $M_{26}$ | 0-5 | Negligible | | $P_{26}$ | 0-5 | Negligible |
| | $M_{27}$ | 5-10 | Poor | | $P_{27}$ | 0-5 | Negligible |
| | $M_{28}$ | 0-5 | Negligible | | $P_{28}$ | 0-5 | Negligible |
| | $M_{29}$ | 5-10 | Poor | | $P_{29}$ | 0-5 | Negligible |
| | $M_{30}$ | 10-15 | Fair | | $P_{30}$ | 0-5 | Negligible |

Based on Table 5, the scale of rock porosity in the Maros Karst Region varies from 0-5%, 5-10%, 10-15%, and 5-50%. The quality of rock porosity in the Maros Karst Region is special with a scale of 5-50% for the $M_1$ sample, the category is sufficient with a scale of 10-15% for the $M_{30}$ sample, 7 (seven) samples have poor quality with a scale, and 21 other samples have good quality. neglected because it is only able to store a very small amount of fluid. In the Pangkep Karst Area, for the entire rock sample, the quality of rock porosity is negligible.

Based on the porosity scale, it can be assessed in the form of rock quality. The assessment is based on the Koesoemadinata (1978) standard in assessing rock quality. The special rock quality shows that the rock has a porous nature because it has a high porosity value and has a very large ability to store water reserves or as a reservoar. On the other hand, negligible quality indicates that the rock has non-porous properties, so it is not suitable to be used as a reservoar because its porosity is very small and even unable to store water even in small quantities.

Based on the results of the physical properties of the rocks that have been obtained, there are 21 (twenty-one) rock samples which are dolomite limestone and 9 (nine) other samples are karstified limestone, it can be evaluated that the karstified limestone in the Maros Karst Area which has special quality can be utilized as a reservoar for clean water reserves. Based on references from the journal (Permana et al., 2020), limestone with high porosity can potentially be used as a groundwater reservoar. The quality is negligible, which is a type of dolomite limestone with a low porosity number on a scale of 0-5%, it cannot be used as a reservoar. Based on references from the journal (Mulyati et al., 2016), dolomite limestone can be used as coarse aggregate instead of gravel for normal concrete mixes.

Rocks in the Maros Karst Area have special qualities with properties that are quite dense and porous, so they can be recommended as reservoars and rocks in the Pangkep Karst Area have negligible porosity, making them suitable as aggregates because they are quite dense and rigid, not easy to absorb water, so it lasts longer, and doesn't have a lot of pores. In addition, the dolomite rock obtained in the Pangkep Karst Area, especially at Location IV, can be recommended as a marble quarry.

## Conclusion

Based on the results of the research that has been done, it can be concluded that the rock density value in the Maros Karst Area is in the range of 1.50-2.68 g/cm $^3$ which indicates the type of limestone and the type of dolomite rock for the Pangkep Karst Area with a density value between 2.47-2.65 g/cm$^3$. The value of rocks porosity in the Maros Karst Area is in the range of 0-50% indicating modified limestone and dolomite limestone and in the Pangkep Karst Area it is in the range of 0-5% indicating dolomite limestone. The type of rock porosity in the Maros Karst Area is secondary porosity and the type of porosity in the Pangkep Karst Area is primary porosity. The difference t-test shows that there is a significant difference between the physical properties of the rocks in the Maros Karst Area and the Pangkep Karst Area based on differences in the density values (original, dry, and saturated) of rocks and rock porosity. The valuation of the physical properties of rocks in the Maros Pangkep Karst Area is in the form of rock quality, namely the rock in the Maros Karst Area has a special quality with a porosity scale of 5-50%, sufficient quality with a porosity scale of 10-15%, poor quality with a porosity scale of 5-10%, and quality is negligible with a 0-5% porosity scale. The results of the valuation of the physical properties of rocks in the Pangkep Karst Area have negligible quality with a porosity scale of 0-5%.

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