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Analysis of Microfaces and Depositional Environment of Limestone in North Isimu Area, Gorontaolo Regency

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Abstract

The geological conditions in the northern part of Lake Limboto vary greatly from the constituent rocks to the working geological structures. Lithological variations consist of volcanic and plutonic rocks to limestone. The area where limestone is widely distributed is in the North Isimu Region, Gorontalo Regency. This research aims to analyze the geological conditions, microfacies and depositional environment of limestone in the North Isimu Region, Gorontalo Regency. The research methods to achieve this goal include field surveys and petrographic laboratory analysis. Field surveys include taking rock samples, coordinating points and elevations, making geomorphological observations, observing geological structures, and taking field documentation. Meanwhile, petrographic analysis of rocks uses a polarizing microscope as a tool to follow up megascopic observations. Observation of rock incisions under a microscope using cross Nicol and parallel Nicol. The results and discussion show that the geomorphology of the research area includes structural hills with sub-parallel river flow patterns. The geological structure of the research area is a descending fault trending northwest-southeast. The research area is divided into four facies, namely foraminifera wackestone, crystalline limestone, foraminifera algae packstone and coralline floatstone. Standard microfacies (SMF) in the North Isimu Region consist of three SMFs, namely SMF-3, SMF-4 and SMF-5, with two limestone depositional environmental zones, namely toe of slope (FZ-3) and slope (FZ-4). FZ-3 was deposited at the end of the foreslope zone, and FZ-4 was deposited seaward from the edge of the carbonate debris platform.

Keyword: Limestone; Microfacies; Depositional Environment; North Isimu

INTRODUCTION

Rocks resulting from the evaporation and deposition of carbonate material originating from the oceans or rock organisms when organisms build shells with a marine depositional environment are limestone (Maryanto, 2021). Limestone has a distinctive texture and characteristics because geological processes form it. This geological process can provide information or data regarding the depositional environment and the limestone age formed in an area. The depositional environment of limestone can be determined based on the characteristics of texture, structure, and fossil content. The abundance of limestone is usually found on the bottom of tropical seas with warm, shallow, and clean water conditions (Korneeva et al., 2019; Permana et al., 2021; Lubis et al., 2021; Adhari & Hidayat, 2023).

Microfacies study is one of the supporting factors in determining the depositional environment because the study of microfacies aims to determine the depositional environment and the depositional facies of limestone (Feng, 2019; Özyurt et al., 2020; Bourli et al., 2021; Abbas et al., 2023; Yousef et al., 2023; Rahmawati et al., 2023; Wang et al., 2023).

Lithotectonically, Gorontalo is included in the northern part of the western

Mandala. The formation of volcanic and sedimentary rocks in the Gorontalo area occurred continuously from the Eocene to the Quaternary, with a depositional environment from land to the deep sea. The Gorontalo area is composed of igneous, pyroclastic, and sedimentary rocks. Limestone is included in sedimentary carbonate rocks with a distribution area of around 14,073 hectares in the Limboto region and its surroundings. The geology of the North Isimu area consists of two rock units, namely limestone units and andesite rock units (Permana et al., 2023; Suarno et al., 2023).

Previous researchers have carried out geological mapping in the North Isimu area on a large scale of 1: 250,000 (Manyoe et al., 2020; Baruadi et al., 2022). This study discusses the geological conditions and development of the North Isimu area, which includes geomorphology, geological structure stratigraphy, and geological history of the research area. Based on the distribution of rock units, the North Isimu Region has four rock units: basalt units, wackestone limestone units, packstone limestone units, and alluvial units.

The novelty of the research lies in the fact that the research location has never been carried out in detailed geological mapping. This research will produce new geological and limestone facies maps at a detailed scale of 1:10,000. Apart from that, the existing limestone research is still descriptive for determining the name of limestone, while analysis of microfacies and depositional environments has never been carried out. This research is very important because it will produce new findings.

This research aims to explore the geological conditions of the North Isimu area, the microfacies of limestone in the North Isimu area, and the limestone depositional environment of the North Isimu area.

RESEARCH METHODS

The research location is in Isimu Utara Village, Tibawa District, Gorontalo Regency (Figure 1). Geographically, the research location is at the coordinates N 00˚40'0" - 00˚41'0" to E 122˚052'30" - 122˚053'45" with a research area of 5 km².

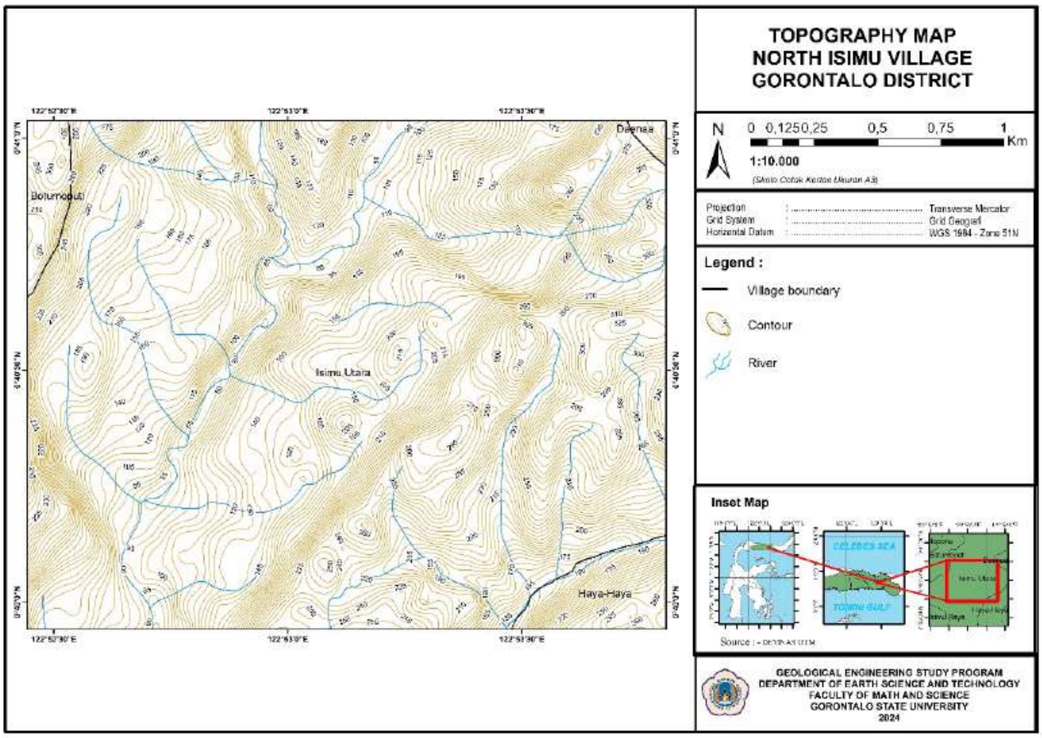

Figure 1. Topographic map of the research area of North Isimu Village, Gorontalo Regency (Source: Primary Data, 2023)

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The method used in this study consisted of two stages, namely, the field observation stage and the data analysis stage. The field observation phase includes data collection on geomorphology, petrology, geological structure, and rock sampling. The rock samples taken will be analyzed petrographically at the Mineralogy and Petrography Laboratory of the Geological Engineering Study Program, Universitas Negeri Gorontalo (Figure 2).

The stages of petrographic analysis begin by forming thin incisions using the blocking method, which infiltrates the blue dye into the pores to distinguish the original rock pores from those created during the preparation.

Figure 2. Petrographic analysis of limestone samples from the North Isimu area (Source: Primary Data, 2023)

Petrographic analysis was carried out with a polarizing microscope equipped with a camera connected to a computer (Payuyu et al., 2022; Permanadewi & Samodra, 2022; Hutagalung et al., 2021; 2023).

This petrographic analysis is very important for determining the name of the rock and limestone microfacies. The rock naming used is a classification from Embry classification from Dunham (Permana et al., 2021). Determining the limestone microfacies' name will help interpret the depositional environment (Permana, 2019; Permana et al., 2021; 2022).

The research framework is described in detail in the flow diagram that has been created (Figure 3).

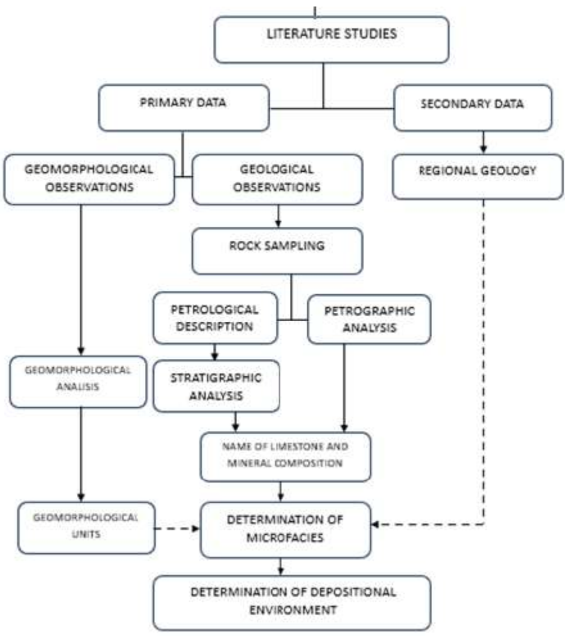

Figure 3. Research Flow Diagram (Source: Primary Data, 2023)

RESULTS AND DISCUSSION

Geomorphology

The geomorphology of the study area includes a landscape dominated by hills with elevation contour intervals of 60-350 meters above sea level—Morphography of low hills to hills with steep to steep slopes. The topography is from undulating to hilly, with an obtuse V-shape of valleys. The flow pattern in the study area is a sub-parallel flow pattern, with the lithology that makes up this geomorphological unit clastic limestone. The active morph structure is in the form of faults, and the morphodynamics shows high erosion and weathering. Based on the Van Zuidam Classification (Hutagalung et al., 2021), the geomorphology of the study area is a structural hill unit.

The genetic type of the river in the study area is consistent. Consequent rivers are rivers whose flow direction is the same as the slope. Where the direction of flow is relatively north-south. The river stadia in the study area include the young stadia with sub-parallel flow patterns and characteristics of rivers experiencing erosion processes.

Limestone Facies

The analysis results show that the limestone in the study area is classified into six facies: foraminifera wackestone, crystalline limestone, foraminifera algae packstone, and corallinefloatstone. The distribution map of the limestone facies is shown in Figure 4.

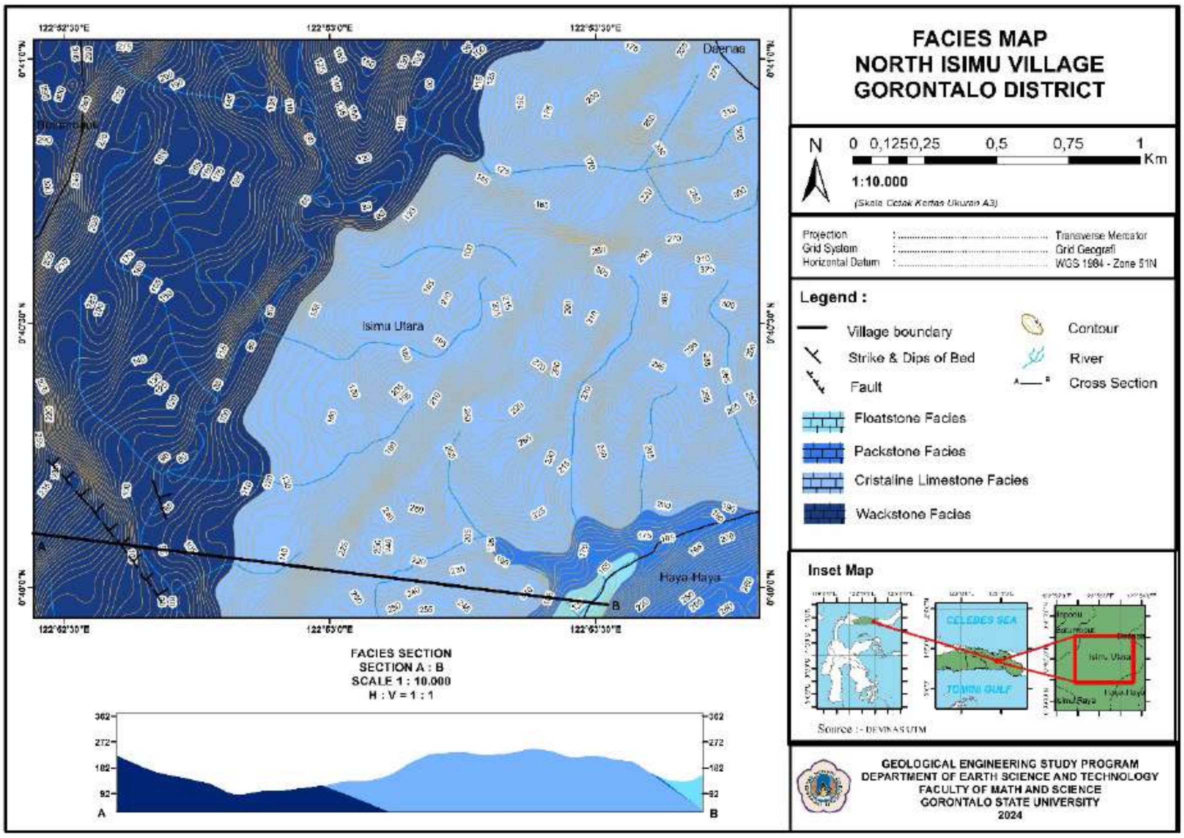

Figure 4. Map of the distribution of limestone facies in the North Isimu Region, Gorontalo Regency (Source: Analysis Results, 2023)

1. Foraminifera Wackestone Facies

Some outcrops are weathered (black) in these facies, and some are still fresh (yellow) with a North-South outcrop direction. Based on field data, the limestone in the study area is fresh yellow, mud-supported, has closed packing, good sorting, massive structure, and carbonate (Figure 5).

Figure 5. Foraminifera wackestone facies outcrop (Source: Primary Data, 2023)

Microscopically, the foraminifera wackestone facies is brownish yellow, the interference color is golden yellow, with a particle size <0.1 – 1.2 mm, material abundance >2mm as much as 0%, mud-supported texture, and open packaging. Based on its composition, the rock is composed of skeletal grains in the form of foraminifera and algae, non-carbonate grains in the form of the mineral quartz, volcanic lithic, and iron oxide with a matrix in the form of micrite. In addition, carbonate cement is present in the form of calcite with blocky and meniscus structures (Figure 6).

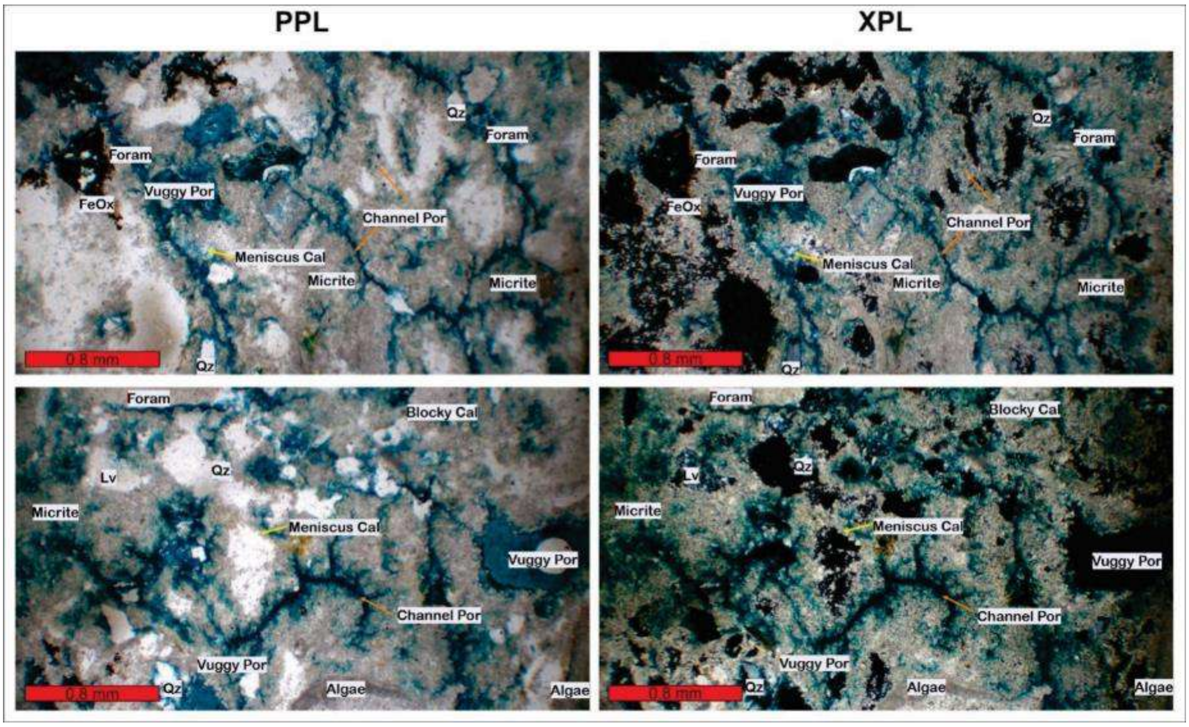

Figure 6. Analysis of foraminifera wackestone facies under a microscope (Source: Primary Data, 2023)

2. Crystalline Limestone Facies

Some outcrops are weathered in these facies, and some are still fresh in a north-south direction. Based on field data, the limestone in the study area is fresh yellow, open packed, poorly sorted, laminated structure, carbonate, and calcite minerals (Figure 7).

Figure 7. Crystalline limestone facies outcrop (Source: Primary Data, 2023)

Microscopically, the crystalline limestone facies is a pale yellow, the interference colour is golden yellow, with a particle size of <0.1–0.4 mm, an abundance of material measuring >2 mm is 0%, the rock texture cannot be observed because it has undergone crystallization very intensive. There is an abundance of 3% of porosity, which consists of intercrystalline porosity. Based on its composition, the rock is composed of carbonate cement dominated by calcite and minor dolomite (Figure 8).

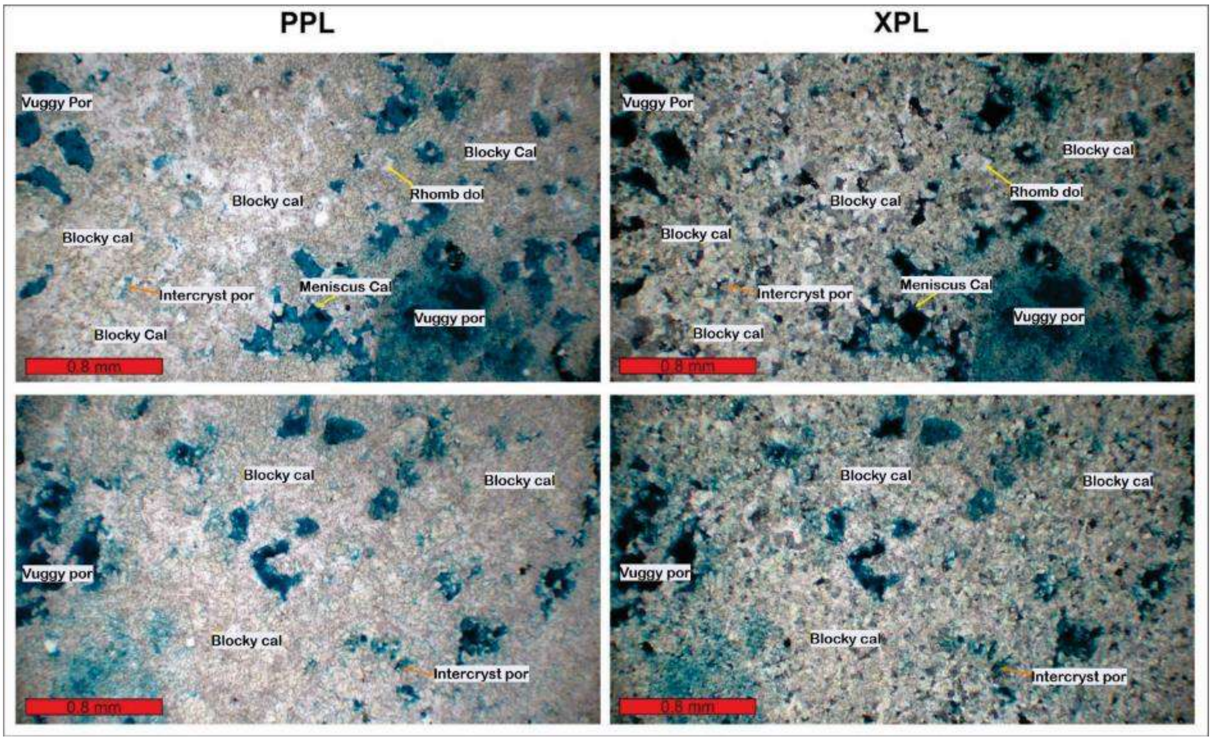

Figure 8. Analysis of crystalline limestone facies under a microscope (Source: Primary Data, 2023)

3. Foraminifera Algae Packstone Facies

Foraminifera algae packstone facies, part of the outcrop, is weathered, and some of it is still fresh with the direction of the outcrop east-southwest. Based on field data, the limestone in the study area is fresh yellow, open-packed, grain-supported, poorly sorted, laminated, and carbonate structures (Figure 9).

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Figure 9. Foraminifera algae packstone facies outcrop (Source: Primary Data, 2023)

Microscopically, the foraminifera algae packstone facies is brownish yellow, interference colour is golden yellow with blue spots, with a particle size <0.1-1.0 mm, material abundance >2 mm is 0%, grain texture is supported, and pack closed. There is an abundance of 7% porosity, which consists of vuggy and interparticle porosity. Based on its composition, rocks are composed of skeletal grains of foraminifera and algae, with a matrix in the form of micrite. In addition, carbonate cement is present in the form of calcite with a meniscus and blocky structure, Foraminifera-algae packstone (Figure 10).

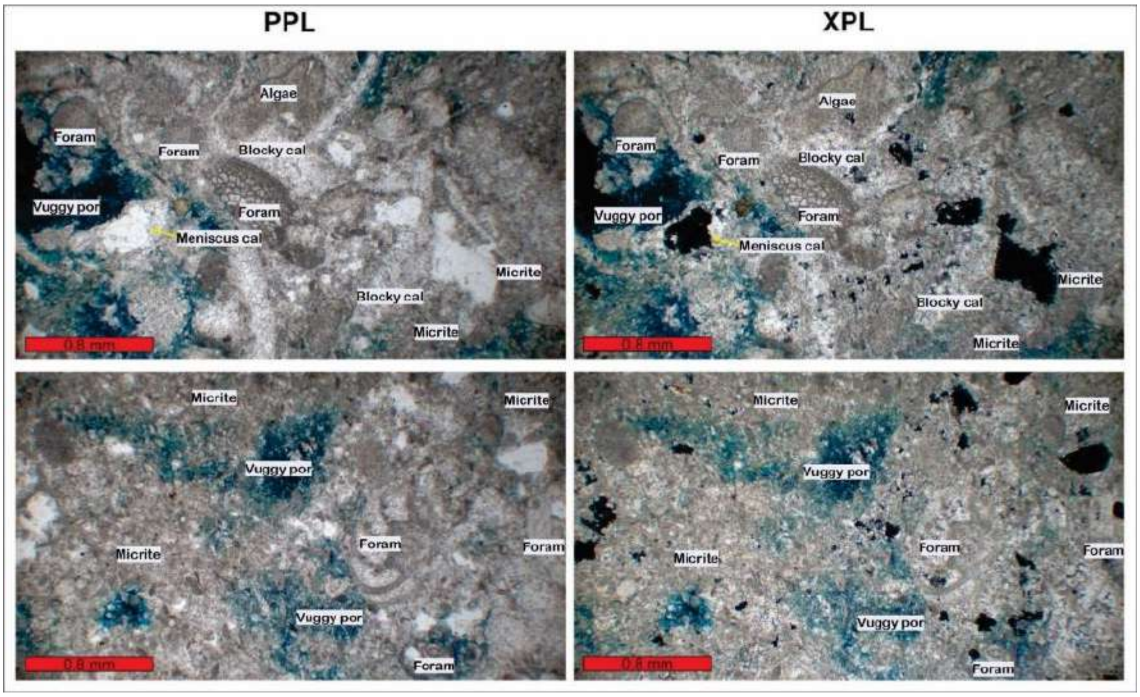

Figure 10. Analysis of packstone algae foraminifera facies under a microscope (Source: Primary Data, 2023)

4. Coralline Floatstone Facies

Fresh condition coralline floatstone facies outcrop with northeast-southwest outcrop direction. Based on field data, the limestone in the study area is fresh yellow, open-packed, matrix-supported, poorly sorted carbonate (Figure 11).

Figure 11. Coralline floatstone facies outcrop (Source: Primary Data, 2023)

Microscopically, the coralline floatstone facies is brownish yellow, golden yellow interference colour with blue spots, with particle size <0.1 – 4.0 mm, material abundance > 2mm as much as 25%, matrix-supported texture, open packaging. There is an abundance of 10% porosity, which consists of a vuggy channel and intraparticle porosity. Based on its composition, the rock is composed of skeletal grains in the form of coral fragments, with a matrix in the form of micrite. In addition, carbonate cement is present in the form of calcite with minor meniscal structures (Figure 12).

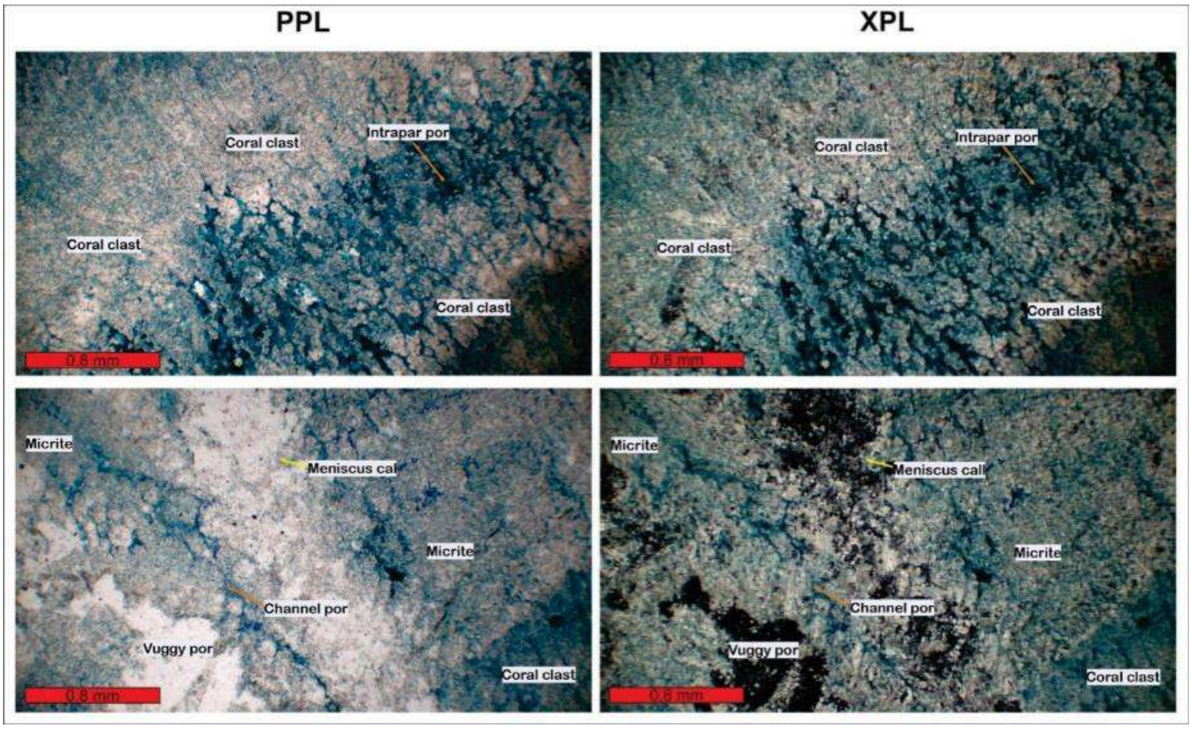

Figure 12. Analysis of coralline floatstone facies under a microscope (Source: Primary Data, 2023)

Microfacies and Depositional Environment

Rock incisions with sample codes LCR-04 and LCR-05 based on petrographic analysis are named Foraminifera-Wackestone and included in standard microfacies (SMF)-3 mudstone and pelagic wackestone with planktonic microfossils. The main feature of this SMF is the presence of a silt matrix and various fossils, such as those found in the 10% LCR-04 foraminifera sample and the 15% LCR-05 foraminifera sample. These microfacies are formed in the toe of the slope environment (FZ-3), referring to the classification of Flugel (Permana et al., 2021)(Figure 13). The edge of the deep sea shelf or the foot of the slope, located on the edge of a basin with a hill of >1.5º with a depth of 200-300 meters, consists of a mixture of oceanic material and fine residues originating from the shallow shelf. Many contain shallow-sea benthic foraminifera, but sometimes also contain deep-sea benthic foraminifera. It consists of packstone, allochthonous grainstone, wackestone, and shale facies.

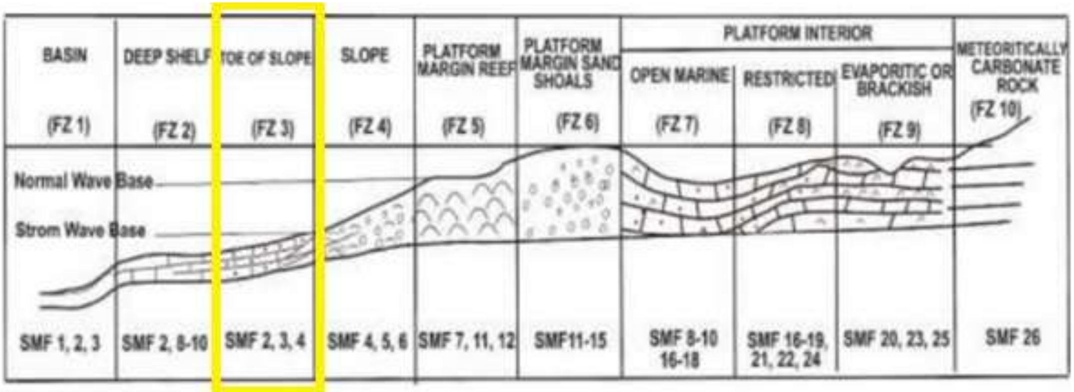

Figure 13. The depositional environment of the foraminifera wackestone microfacies is the toe of slope (FZ 3) (Classification of Flugel in Permana et al., 2021)

Rock incision with sample code LCR-06 based on petrographic analysis is Crystalline Limestone belonging to SMF-4 packstone or bioclastic-litho-clastic rudstone, and micro breccia with the main characteristics of fine-sized breccias, sediment debris, and turbidites consisting of grains from various origins with a layered structure. Granules are generally obsolete and rounded and may consist of local bioclasts, shallow marine materials, or cemented lithoclases, such as in the LCR-06 sample, which has 95% calcite cement and 5% dolomite cement. These microfacies were formed on slope conditions (FZ-4). The slope is located on the edge of the shelf facing the sea, with a slope of 5º to vertical. It contains material that results from decay from exposure and is mixed with pelagic. It has a very variable grain size and presents benthic foraminifera, shallow marine benthic foraminifera, and deep-sea plankton. It consists of allochthonous packstone, grainstone, floatstone, mudstone, and claystone facies. Rock incision with sample code LCR-08 based on petrographic analysis is Foraminifera-algae Packstone belonging to SMF-5 grainstone, rudstone, packstone, and floatstone or bioclastic alokton breccia with the main characteristic being the presence of intact and broken fossil-containing rocks dense and compressed from organisms originating from reefs, such as in the LCR-08 sample containing 15% Red Algae and 40% Foraminifera. Furthermore, the rock incision with sample code LCR-07 based on petrographic analysis is Coralline Floatstone included in SMF-5, which has a 25% coral rubble content. The two facies were formed on a slope (FZ-4), located on the edge of the shelf facing the sea, with a slope of 5º to the vertical. It contains material that results from decay from exposure and is mixed with pelagic. It has a very variable grain size and presents benthic foraminifera, shallow marine benthic foraminifera, and deep-sea plankton. It consists of allochthonous packstone, grainstone, floatstone, mudstone, and claystone facies (Figure 14).

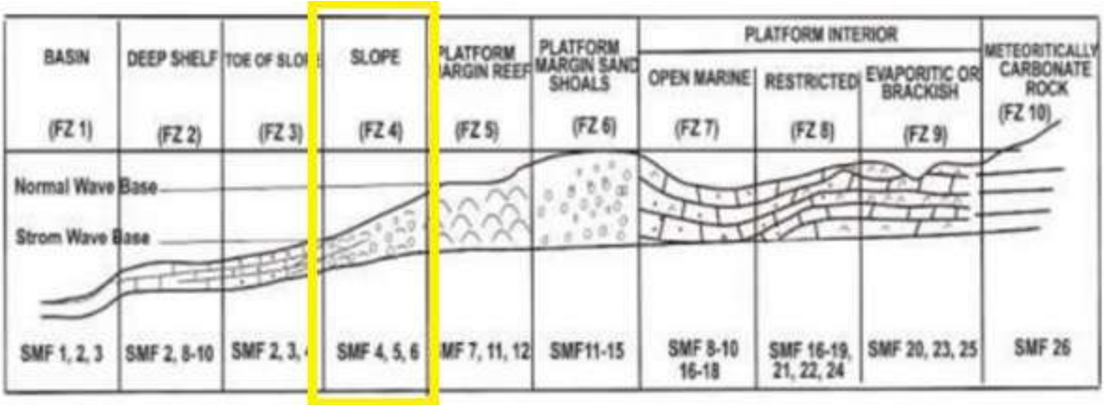

Figure 14. The depositional environment of crystalline limestone, foraminifera algae packstone and coralline floatstone microfacies is a slope (FZ 4) (Classification of Flugel in Permana et al., 2021)

Geological Structure

Straightness analysis using Demnas data is then processed using the Dips application to create a rosette diagram. The analysis of the rosette diagram shows that the research location experienced two tectonic phases. The oldest tectonic phase has a north-south alignment pattern, while the youngest has a northwest-southeast pattern. Field observations show a down fault structure trending northwest-southeast with the strike/dip direction N 310^{o} E/45^{o}NE. The down fault cuts the foraminifera wackestone facies.

The geological history of the research area begins in the middle to late Pliocene (N20-21 or 5.3 to 2.5 million years ago) in a deep sea depositional environment, namely the lower bathyal with a depth of 1800 to 2400 meters below sea level, the first facies deposited wackestone limestone with a thickness of 1250 meters which has a dominant composition of foraminifera and red algae fossils. Then, after the wackestone limestone was formed in the lower bathyel, the depositional environment experienced uplift during the late Pliocene (N21 or 2.5 million years ago) to become deep sea, namely the middle bathyel with a depth of 1300-1800 m below sea level, forming a packstone limestone facies with a thickness of 75 meter which has a dominant composition of foraminifera fossils and red algae.

During the process of forming packstone limestone, some of the wackestone limestone experiences crystallization due to the lifting and loading processes originating from the packstone limestone, resulting in the formation of crystalline limestone facies with a thickness of 600 m with a dominant composition of calcite cement and dolomite cement. Next, it underwent a process of uplift into the upper bathyel with a depth of 500-1300 meters below sea level during the late Pliocene to early Pleistocene (N21-N22 or 2.5 to 1.8 million years ago), forming a floatstone limestone facies with a thickness of 50 meters whose composition was The dominant coral fragments are interpreted as originating from shallower depositional environments. During the late Pleistocene (1 million years ago), the depositional basin experienced an uplift to the surface to become a lake plain characterised by a lake plain to the south of the research location. The uplift continued until the Holocene, which made the research location what it is now, namely having a height of up to 350 meters above sea level.

CONCLUSION

From the results of research on the microfacies and depositional environment of limestone in the Isimu Utara Region, Gorontalo Regency, it can be concluded that the geomorphology of the study area is included in structural hills with a sub-parallel river flow pattern. The research area is divided into four facies: foraminifera wackestone, crystalline limestone, foraminifera algae packstone, and coralline floatstone facies. Standard microfacies (SMF) in the North Isimu Region consist of three SMFs, namely SMF-3, SMF-4, and SMF-5, with two environmental zones of limestone deposition, namely the toe of slope (FZ-3) and slope (FZ-4). The geological structure of the study area, which works in the research area, is a descending fault trending northwest-southeast with a value of N 310° E/45°NE.

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