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New Journal Proposal

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Aang Panji Permana <aang@ung.ac.id>

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December 03, 2020

Editor in Chief of News of the National Academy of Sciences of the Republic of Kazakhstan-Series of Geology and Technical Sciences

Dear Editor of News of the National Academy of Sciences of the Republic of Kazakhstan-Series of Geology and Technical Sciences,

We are submit a manuscript for consideration of publication in News of the National Academy of Sciences of the Republic of Kazakhstan-Series of Geology and Technical Sciences. The manuscript is entitled "**Microfacies and Depositional Environment of Tertiary Limestone, Gorontalo Province, Indonesia**" to be considered published.

The method and results of our research the level of novelty are high.

These informations are very interesting for the development of stratigraphy, microfasies and petrology of carbonate rocks in the field for scientists, researchers, and lecturers who read our journals.

This manuscript has not been published elsewhere and that it has not been submitted simultaneously for publication elsewhere.

Thank you for receiving our manuscript and considering it for review. We value the time of the Board of Editor and we await your response from the Board of Editor.

Thank you very much for your consideration.

Yours Sincerely,

Aang Panji Permana

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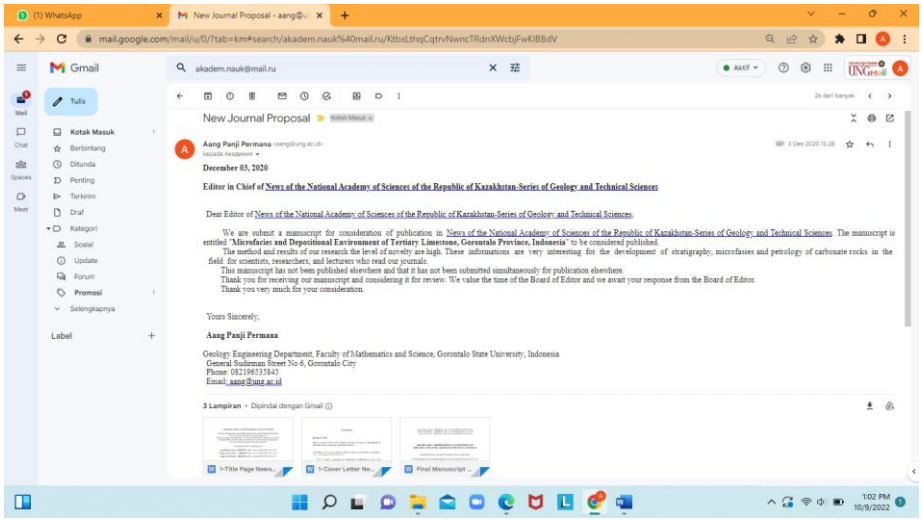

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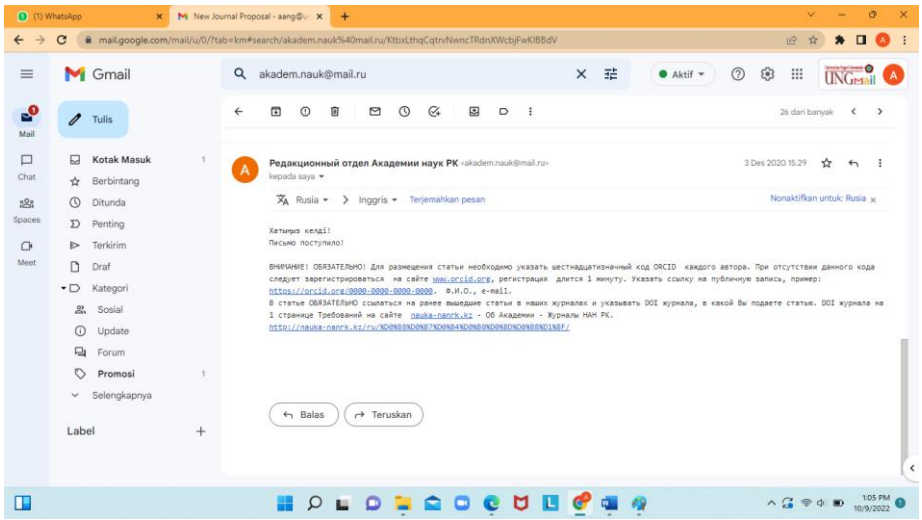

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MICROFACIES AND DEPOSITIONAL ENVIRONMENT OF TERTIARY LIMESTONE, GORONTALO PROVINCE, INDONESIA

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Abstract. The research area is located in northern Limboto Lake in Gorontalo Province, which has complex geological characteristics. The geological complexities include stratigraphy and tectonics which influence the formation of the Limboto Basin. Limestone research in the Late Tertiary Limboto Basin is very intriguing to be done because of the lack of research in limestone. Gorontalo limestone outcrops, which become the focus of the research, have a total thickness of 30 meters. The research objective is to analyze facies, microfacies, and depositional environment of tertiary limestone. These two research objectives are attained by using two research methods, namely measurd section and petrography analysis. The research result exhibits that there are four Gorontalo limestones facies, including coralline rudstone intercalated with thin mudstone facies, sandy micrite intercession facies, coralline rudstone intercession facies and sandy allochem limestone intercession facies. According to the limestone microfacies standard, the depositional environment of Gorontalo limestone is platform interior restricted (facies zone 8).

Keywords: Microfacies, Depositional Environment, Tertiary Limestone, Gorontalo

1. Introduction

Sulawesi Island has tectonic and geological complexity. This complexity is influenced by the collision of three plates, namely the Eurasian Plate, the Indo-Australian Plate, and the Pacific Plate. The interaction of these three plates causes a striking change from the shape of the Sulawesi island, changing from an archipelago with a convex side towards the Pacific Ocean to the K shape as it is now. The collision of the moving Pacific plate pushes Sulawesi westward along 800 km [1, 2].

Sulawesi complexity makes this island can be divided into several tectonic provinces including pluton and volcanic rocks composing the West Sulawesi arm, the metamorphic belt composing Central Sulawesi, ophiolites composing East Sulawesi and the continental micro blocks of Banggai-Sula and Buton-Tukang Besi [3, 4].

The north arm of Sulawesi, which is part of the West Sulawesi arm, is also composed of volcanic rock, which is estimated to be of late Paleogene and Neogene origin from the Maluku plate and Sulawesi Sea plate subduction zone [5]. The middle part of the Sulawesi North Arm lies the Limboto plain formed by Limboto Lake and several rivers. The constituent rocks in this basin are limestone. Quaternary limestone spread to the northwest of Lake Limboto with an area of 20 x 4 km2 of Pliocene-Pleistocene age and in the west and south an area of 37 x 4 km2 of Pleistocene age [6, 7].

The distribution of Quaternary age rocks is closely related to the various forms of morphology and basin shapes produced by the last tectonic process which developed since the time of the Late Miocene epoch, volcanic activity, and denudation processes. Quaternary rock distribution can be known from remote sensing imagery, both with aerial portraits, radar, and Landsat. The alluvial plateau and elevated coral limestone that spread out wide shows the stability of the bedrocks [7, 8].

Limestone research in Lake Limboto has been done by creating a regional geological map. Two limestone formations consist of Clastic Limestone Formation and Coral Limestone Formation. The Pliocene-Pleistocene Clastic Limestone Formation is located in the west of the lake comprising calcarenite, calcirudite and coral limestone with the thickness up to 200 meters. Coral Limestone Formation (Ql) which is located in the south of the lake is estimated to be Holocene; this reef limestone is uplifted with the main component of coral [9].

Limestone research in Limboto Lake has only been carried out in general by producing regional geological maps. Two limestone formations are Clastic Limestone Formation and Reef Limestone Formation. The Clastic Limestone Formation located in the western lake is Pliocene-Pleistocene lake with calcarenite lithology, calcirudite and coral limestone with thickness up to 200 meters. The Reef Limestone Formation (Ql) found in the south of the lake is estimated to be Holocene in age; this reef limestone is elevated with coral as the main component [9].

Limestone research in the Yosonegoro area produces two facies and microfacies, namely coraline rudstone facies and wackestone-packestone intercession facies with a slope to toe of slope depositional environment [10]. Limestone research in the north of Lake Limboto is carried out due to a lack of research data on Gorontalo limestone. Hence, this research is carried out in detail by taking a more comprehensive approach from the geological aspect so that new findings will be generated. The research aims to analyze microfacies, depositional environments, relative age and paleobathymetry of Gorontalo limestone, which involves microfacies and biostratigraphy analysis methods.

2. Research Method

The location of the research is the West Limboto District of Gorontalo Regency in the North of Lake Limboto with the geographical location at coordinates (00° 39' 5"- 00° 39' 7.644" North) and (122° 55' 20.833"- 122° 55' 34" East) (Figure 1). Materials and research supplies are limestone outcrops with a thickness of up to 30 meters. The research method consists of two stages. The first stage is doing a measured section (MS) using a 1.5 meter interval jacob's staff systematically from the oldest to the youngest rocks [10, 11, 12, 13].

This method is fundamental to know the facies in the study site, including measuring the exact thickness of the facies and taking appropriate samples for petrographic analysis. The next method is the petrographic analysis of a thin section using a 1053 polarization microscope equipped with a computer-connected camera. The petrographic analysis is beneficial in determining microfacies so that the depositional environment can be easily determined [14, 15].

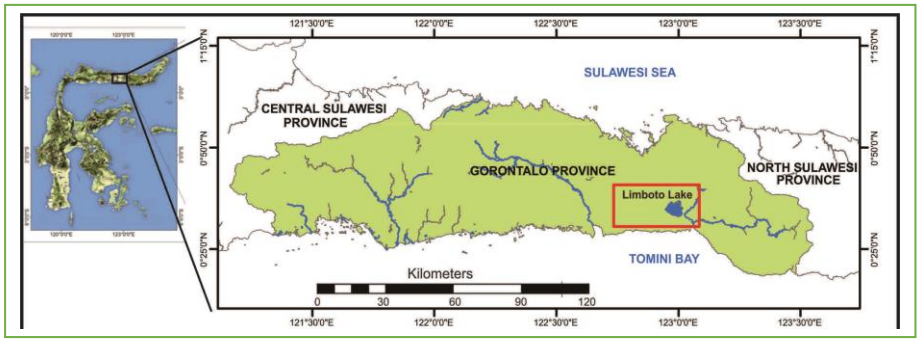

Figure 1. Research location which is located on the north of Lake Limboto, West Limboto District, Gorontalo Regency.

3 Research Results and Discussion

A. Facies and Microfacies

MS measurements are carried out in detail by distinguishing one facies unit to another facies. The reference to differentiate these facies is done by doing field descriptions and petrology based on texture, structure, and composition. Determination of standard microfacies (SMF) in addition to the initial data distribution of facies and sedimentary structures found in the field as well as the detailed composition of petrographic analysis. MS results at the research site contain four facies, namely facies A, B, C, and D (Figure 2). Descriptions of the four facies are as follows:

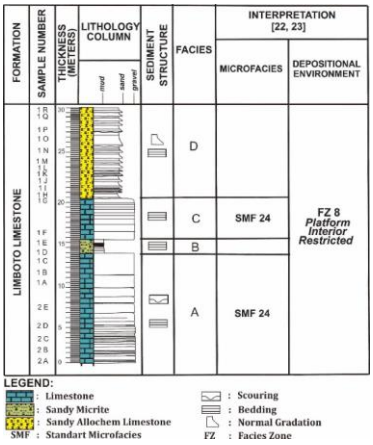

Figure 2. Lithostratigraphic distribution chart which divides Gorontalo limestone into four facies

Facies A is interpreted as coralline rudstone intercalated with thin mudstone facies [16]. The coralline rudstone intercalated with thin mudstone facies are at the bottom of the lithostratigraphic column. The position of this facies is at intervals of 0-13 meters. This facies is described as brownish-white, grain size> 2 mm, poor sorting, rough fragmental bioclastic texture, open packaging, the connection between grain is floating in the matrix. The bedding structure is thickining upward and the scouring structure is at the top of the contact with the mudstone. The rock composition is composed of coral fragments, micrite, and opaque minerals. The composition of these facies based on petrographic analysis consists of red algae (7%), foraminifera (8%), corals (10%), brachiopods (4%), bryozoa (2%), mollusks (1%), echinoids (1%)), and non-skeletal shells in the form of peloids (15%). Granules are embedded in the matrix in the form of carbonate mud (5%) with cementation (30%) in the form of microspar-pseudospar. Found a cavity of vuggy (3%), intercrystalline (10%), intercrystalline (0.5%), and cracks (0.5%); replacement is characterized by the presence of clay minerals (3%) (Figure 3).

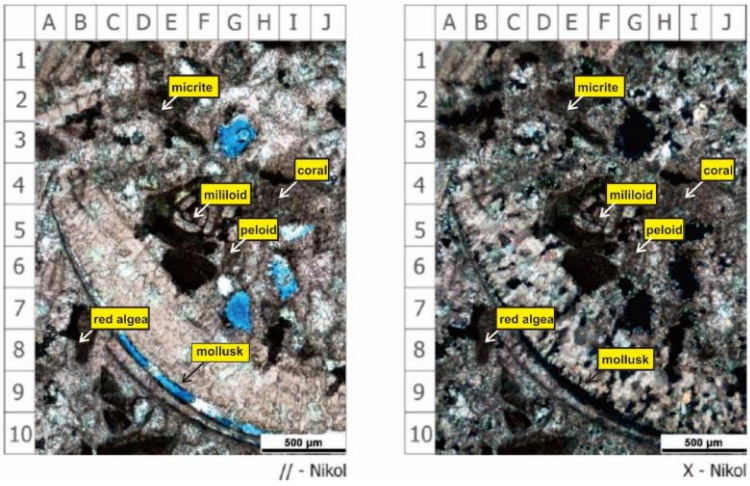

Figure 3. Petrographic analysis of coralline rudstone samples [16], which is Facies A

Based on the composition of these facies, the type of microfacies is SMF 24 [17, 18]. The reason is that these microfacies are composed of coarse bioclasts and are influenced by slope or imbrication with sparse matrices. The depositional environment for microfacies based on the type of SMF 24 is the restricted interior platform (FZ 8) (Figure 4).

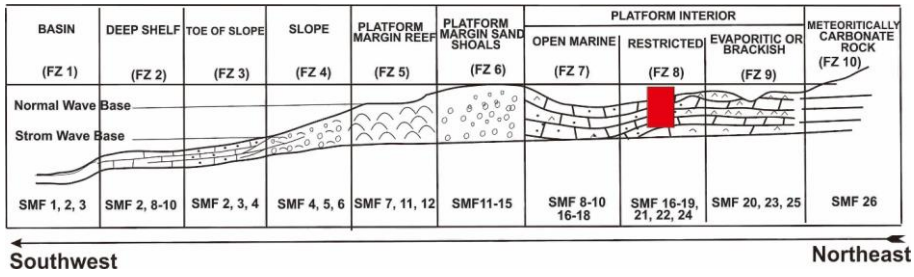

Figure 4. Gorontalo limestone depositional environment, which is a platform interior restricted (FZ 8) [17, 18]

Facies B is interpreted as sandy micrite intercession facies [19]. This facies is above the coralline rudstone intercalated with thin mudstone facies of the lithostratigraphic column. The position of these facies is at intervals of 13-15 meters. Further, this facies is described as brown, grain-size silt (1/256-1/16 mm), good sorting, closed packaging, composition: micrite and quartz with some rock fragments. The structure of this facies is bedding (thinning upward). The interpretation of depositional energy is high.

The composition of these facies is based on petrographic analysis consisting of small foraminifera (1%), and non-skeletal granules in the form of plagioclase (2%), quartz (3%), hornblende (1%), carbon (7%), opaque minerals (5%), and rock fragments (1%) embedded in the matrix (40%) with cementation (25%) of the cavity in the form of vuggy (5%). Substitution is characterized by the presence of clay minerals (10%).

Facies C is interpreted as coralline rudstone intercession facies [16]. The coralline-rudstone intercession facies are above the sandy micrite intercession facies of the lithostratigraphic column. The position of these facies is at intervals of 15-20.5 meters. This facies description is brownish-white, grain size> 2 mm, poor sorting, rough fragmental bioclastic texture, open packaging, the connection between grains is floating in the matrix. The structure is bedding (thinning upward).

Based on the composition of these facies, the type of microfacies is SMF 24 [17, 18]. The reason is that these microfacies are composed of coarse bioclasts and are influenced by slope or imbrication with sparse matrices. The depositional environment for microfacies based on the type of SMF 24 is the restricted interior platform (FZ 8) (Figure 4).

Facies D is interpreted as sandy allochem limestone intercession facies [19]. This facies is above the coralline rudstone intercession facies from the lithostratigraphic column. The position of this facies is at intervals of 20.5-30 meters. This facies description is a light brown, fine-sized grain (1/8-1/4 mm), good sorting, and closed packaging. Further, the structure are bedding (thickining upward) and normal gradation with the composition of the micrite, quartz, and feldspar. The interpretation of formation energy based on grain size is high.

Moreover, the composition of these facies is based on petrographic analysis consisting of small foraminifera (8%), red algae (2%), echinoids (3%), bryozoa (5%), corals (5%), and large foraminifera (5%). Meanwhile, non-skeletal granules consist of opaque minerals (1%), hornblende (1%), plagioclase (2%), quartz (10%), rock fragments (3%), peloids (7%), carbon (1%)), actinolite (1%) embedded in the matrix (13%) in the form of a small amount of carbonate mud and cementation (7%) in the form of calcite spines and clay minerals (2%). Porosity (25%) is vuggy and moldic.

4 Conclusion

The research of microfacies and depositional environments of tertiary limestone, Gorontalo Province, Indonesia yielded several essential points which become the conclusions, including:

1. The facies analysis of tertiary limestone consists of four types of facies, namely coralline rudstone intercalated with thin mudstone facies, sandy micrite intercession facies, coralline rudstone intercession facies and sandy allochem limestone intercession facies.
2. The depositional environment for microfacies based on the type of SMF 24 is the restricted interior platform (FZ 8).

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Journal Revision Instructions

The article has been sent for review

Kotak Masuk

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Good afternoon!
The article is registered in the journal “News of the NAS RK. Series of Geology and Technical Sciences "No.2, 2021 because minor revison.

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Dear Editor

thanks for the information

Regards
Aang Panji Permana

Aang Panji Permana <aang@ung.ac.id> 11 Jan 2021 18.03

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Dear Editor

We are looking forward to hearing about when a letter of accepted for our journal will be sent with the title "MICROFACIES AND DEPOSITIONAL ENVIRONMENT OF TERTIARY LIMESTONE, GORONTALO PROVINCE, INDONESIA" including the fee for publication. Because on Saturday (January 9, 2021) we submitted another new journal proposal with the title "THE ANALYSIS OF SLIDING SURFACE IN ALO WATERSHED, GORONTALO DISTRICT, INDONESIA" which is still waiting for the editor's decision if accepted, we are ready to transfer fees for the two journals as soon as possible. Thank you for your attention.

Regards
Aang Panji Permana

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Yes. There is such an article.

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Abstract. The research area is located in northern Limboto Lake in Gorontalo Province, which has complex geological characteristics. The geological complexities include stratigraphy and tectonics which influence the formation of the Limboto Basin. Limestone research in the Late Tertiary Limboto Basin is very intriguing to be done because of the lack of research in limestone. Gorontalo limestone outcrops, which become the focus of the research, have a total thickness of 30 meters. The research objective is to analyze facies, microfacies, and depositional environment of tertiary limestone. These two research objectives are attained by using two research methods, namely measurd section and petrography analysis. The research result exhibits that there are four Gorontalo limestones facies, including coralline rudstone intercalated with thin mudstone facies, sandy micrite intercession facies, coralline rudstone intercession facies and sandy allochem limestone intercession facies. According to the limestone microfacies standard, the depositional environment of Gorontalo limestone is platform interior restricted (facies zone 8).

Keywords: Microfacies, Depositional Environment, Tertiary Limestone, Gorontalo

1. Introduction

Sulawesi Island has tectonic and geological complexity. This complexity is influenced by the collision of three plates, namely the Eurasian Plate, the Indo-Australian Plate, and the Pacific Plate. The interaction of these three plates causes a striking change from the shape of the Sulawesi island, changing from an archipelago with a convex side towards the Pacific Ocean to the K shape as it is now. The collision of the moving Pacific plate pushes Sulawesi westward along 800 km [1, 2].

Sulawesi complexity makes this island can be divided into several tectonic provinces including pluton and volcanic rocks composing the West Sulawesi arm, the metamorphic belt composing Central Sulawesi, ophiolites composing East Sulawesi and the continental micro blocks of Banggai-Sula and Buton-Tukang Besi [3, 4].

The north arm of Sulawesi, which is part of the West Sulawesi arm, is also composed of volcanic rock, which is estimated to be of late Paleogene and Neogene origin from the Maluku plate and Sulawesi Sea plate subduction zone [5]. The middle part of the Sulawesi North Arm lies the Limboto plain formed by Limboto Lake and several rivers. The constituent rocks in this basin are limestone. Quaternary limestone spread to the northwest of Lake Limboto with an area of 20 x 4 km2 of Pliocene-Pleistocene age and in the west and south an area of 37 x 4 km2 of Pleistocene age [6, 7].

The distribution of Quaternary age rocks is closely related to the various forms of morphology and basin shapes produced by the last tectonic process which developed since the time of the Late Miocene epoch, volcanic activity, and denudation processes. Quaternary rock distribution can be known from remote sensing imagery, both with aerial portraits, radar, and Landsat. The alluvial plateau and elevated coral limestone that spread out wide shows the stability of the bedrocks [7, 8].

Limestone research in Lake Limboto has been done by creating a regional geological map. Two limestone formations consist of Clastic Limestone Formation and Coral Limestone Formation. The Pliocene-Pleistocene Clastic Limestone Formation is located in the west of the lake comprising calcarenite, calcirudite and coral limestone with the thickness up to 200 meters. Coral Limestone Formation (Ql) which is located in the south of the lake is estimated to be Holocene; this reef limestone is uplifted with the main component of coral [9].

Limestone research in Limboto Lake has only been carried out in general by producing regional geological maps. Two limestone formations are Clastic Limestone Formation and Reef Limestone Formation. The Clastic Limestone Formation located in the western lake is Pliocene-Pleistocene lake with calcarenite lithology, calcirudite and coral limestone with thickness up to 200 meters. The Reef Limestone Formation (Ql) found in the south of the lake is estimated to be Holocene in age; this reef limestone is elevated with coral as the main component [9].

Limestone research in the Yosonegoro area produces two facies and microfacies, namely coraline rudstone facies and wackestone-packestone intercession facies with a slope to toe of slope depositional environment [10]. Limestone research in the north of Lake Limboto is carried out due to a lack of research data on Gorontalo limestone. Hence, this research is carried out in detail by taking a more comprehensive approach from the geological aspect so that new findings will be generated. The research aims to analyze microfacies, depositional environments, relative age and paleobathymetry of Gorontalo limestone, which involves microfacies and biostratigraphy analysis methods.

2. Research Method

The location of the research is the West Limboto District of Gorontalo Regency in the North of Lake Limboto with the geographical location at coordinates (00^o 39' 5"- 00^o 39' 7.644" North) and (122^o 55' 20.833"- 122^o 55' 34" East) (Figure 1). Materials and research supplies are limestone outcrops with a thickness of up to 30 meters. The research method consists of two stages. The first stage is doing a measured section (MS) using a 1.5 meter interval jacob's staff systematically from the oldest to the youngest rocks [10, 11, 12, 13].

This method is fundamental to know the facies in the study site, including measuring the exact thickness of the facies and taking appropriate samples for petrographic analysis. The next method is the petrographic analysis of a thin section using a 1053 polarization microscope equipped with a computer-connected camera. The petrographic analysis is beneficial in determining microfacies so that the depositional environment can be easily determined [14, 15].

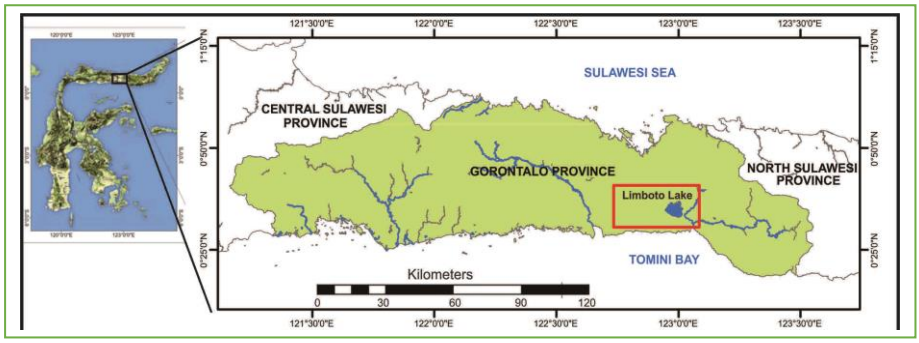

Figure 1. Research location which is located on the north of Lake Limboto, West Limboto District, Gorontalo Regency.

Commented [RV1]: The research location was made in detail to the location where the measurement of the Measrung section (MS)

3 Research Results and Discussion

B. Facies and Microfacies

MS measurements are carried out in detail by distinguishing one facies unit to another facies. The reference to differentiate these facies is done by doing field descriptions and petrology based on texture, structure, and composition. Determination of standard microfacies (SMF) in addition to the initial data distribution of facies and sedimentary structures found in the field as well as the detailed composition of petrographic analysis. MS results at the research site contain four facies, namely facies A, B, C, and D (Figure 2). Descriptions of the four facies are as follows:

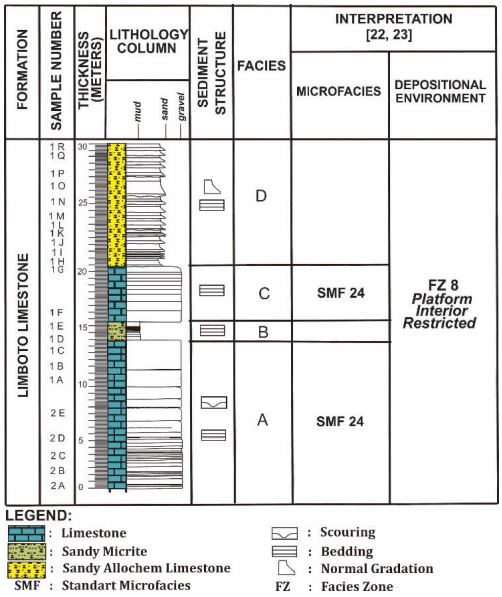

Figure 2. Lithostratigraphic distribution chart which divides Gorontalo limestone into four facies

Facies A is interpreted as coralline rudstone intercalated with thin mudstone facies [16]. The coralline rudstone intercalated with thin mudstone facies are at the bottom of the lithostratigraphic column. The position of this facies is at intervals of 0-13 meters. This facies is described as brownish-white, grain size> 2 mm, poor sorting, rough fragmental bioclastic texture, open packaging, the connection between grain is floating in the matrix. The bedding structure is thickining upward and the scouring structure is at the top of the contact with the mudstone. The rock composition is composed of coral fragments, micrite, and opaque minerals. The composition of these facies based on petrographic analysis consists of red algae (7%), foraminifera (8%), corals (10%), brachiopods (4%), bryozoa (2%), mollusks (1%), echinoids (1%)), and non-skeletal shells in the form of peloids (15%). Granules are embedded in the matrix in the form of carbonate mud (5%) with cementation (30%) in the form of microspar-pseudospar. Found a cavity of vuggy (3%), intercrystalline (10%), intercrystalline (0.5%), and cracks (0.5%); replacement is characterized by the presence of clay minerals (3%) (Figure 3).

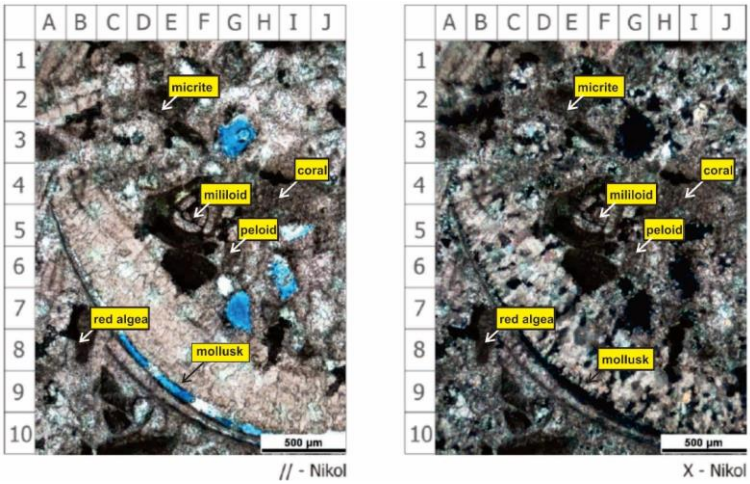

Figure 3. Petrographic analysis of coralline rudstone samples [16], which is Facies A

Based on the composition of these facies, the type of microfacies is SMF 24 [17, 18]. The reason is that these microfacies are composed of coarse bioclasts and are influenced by slope or imbrication with sparse matrices. The depositional environment for microfacies based on the type of SMF 24 is the restricted interior platform (FZ 8) (Figure 4).

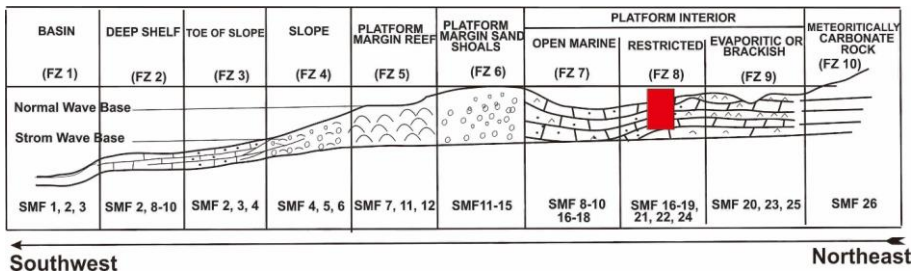

Figure 4. Gorontalo limestone depositional environment, which is a platform interior restricted (FZ 8) [17, 18]

Facies B is interpreted as sandy micrite intercession facies [19]. This facies is above the coralline rudstone intercalated with thin mudstone facies of the lithostratigraphic column. The position of these facies is at intervals of 13-15 meters. Further, this facies is described as brown, grain-size silt (1/256-1/16 mm), good sorting, closed packaging, composition: micrite and quartz with some rock fragments. The structure of this facies is bedding (thinning upward). The interpretation of depositional energy is high.

The composition of these facies is based on petrographic analysis consisting of small foraminifera (1%), and non-skeletal granules in the form of plagioclase (2%), quartz (3%), hornblende (1%), carbon (7%), opaque minerals (5%), and rock fragments (1%) embedded in the matrix (40%) with cementation (25%) of the cavity in the form of vuggy (5%). Substitution is characterized by the presence of clay minerals (10%).

Facies C is interpreted as coralline rudstone intercession facies [16]. The coralline-rudstone intercession facies are above the sandy micrite intercession facies of the lithostratigraphic column. The position of these facies is at intervals of 15-20.5 meters. This facies description is brownish-white, grain size> 2 mm, poor sorting, rough fragmental bioclastic texture, open packaging, the connection between grains is floating in the matrix. The structure is bedding (thinning upward).

Commented [RV2]: Add C facies photo petrographic analysis

Based on the composition of these facies, the type of microfacies is SMF 24 [17, 18]. The reason is that these microfacies are composed of coarse bioclasts and are influenced by slope or imbrication with sparse matrices. The depositional environment for microfacies based on the type of SMF 24 is the restricted interior platform (FZ 8) (Figure 4).

Facies D is interpreted as sandy allochem limestone intercession facies [19]. This facies is above the coralline rudstone intercession facies from the lithostratigraphic column. The position of this facies is at intervals of 20.5-30 meters. This facies description is a light brown, fine-sized grain (1/8-1/4 mm), good sorting, and closed packaging. Further, the structure are bedding (thickining upward) and normal gradation with the composition of the micrite, quartz, and feldspar. The interpretation of formation energy based on grain size is high.

Commented [RV3]: Add D facies photo petrographic analysis

Moreover, the composition of these facies is based on petrographic analysis consisting of small foraminifera (8%), red algae (2%), echinoids (3%), bryozoa (5%), corals (5%), and large foraminifera (5%). Meanwhile, non-skeletal granules consist of opaque minerals (1%), hornblende (1%), plagioclase (2%), quartz (10%), rock fragments (3%), peloids (7%), carbon (1%)), actinolite (1%) embedded in the matrix (13%) in the form of a small amount of carbonate mud and cementation (7%) in the form of calcite spines and clay minerals (2%). Porosity (25%) is vuggy and moldic.

4 Conclusion

The research of microfacies and depositional environments of tertiary limestone, Gorontalo Province, Indonesia yielded several essential points which become the conclusions, including:

3. The facies analysis of tertiary limestone consists of four types of facies, namely coralline rudstone intercalated with thin mudstone facies, sandy micrite intercession facies, coralline rudstone intercession facies and sandy allochem limestone intercession facies.
4. The depositional environment for microfacies based on the type of SMF 24 is the restricted interior platform (FZ 8).

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Revised Results/Authors Response

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MICROFACIES AND DEPOSITIONAL ENVIRONMENT OF TERTIARY LIMESTONE, GORONTALO PROVINCE, INDONESIA

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Abstract. The research area is located in northern Limboto Lake in Gorontalo Province, which has complex geological characteristics. The geological complexities include stratigraphy and tectonics which influence the formation of the Limboto Basin. Limestone research in the Late Tertiary Limboto Basin is very intriguing to be done because of the lack of research in limestone. Gorontalo limestone outcrops, which become the focus of the research, have a total thickness of 30 meters. The research objective is to analyze facies, microfacies, and depositional environment of tertiary limestone. These two research objectives are attained by using two research methods, namely measurd section and petrography analysis. The research result exhibits that there are four Gorontalo limestones facies, including coralline rudstone intercalated with thin mudstone facies, sandy micrite intercession facies, coralline rudstone intercession facies and sandy allochem limestone intercession facies. According to the limestone microfacies standard, the depositional environment of Gorontalo limestone is platform interior restricted (facies zone 8).

Keywords: Microfacies, Depositional Environment, Tertiary Limestone, Gorontalo

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2. Research Method

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The first stage is doing a measured section (MS) using a 1.5 meter interval jacob's staff systematically from the oldest to the youngest rocks [10, 11, 12, 13].

This method is fundamental to know the facies in the study site, including measuring the exact thickness of the facies and taking appropriate samples for petrographic analysis. The next method is the petrographic analysis of a thin section using a 1053 polarization microscope equipped with a computer-connected camera. The petrographic analysis is beneficial in determining microfacies so that the depositional environment can be easily determined [14, 15].

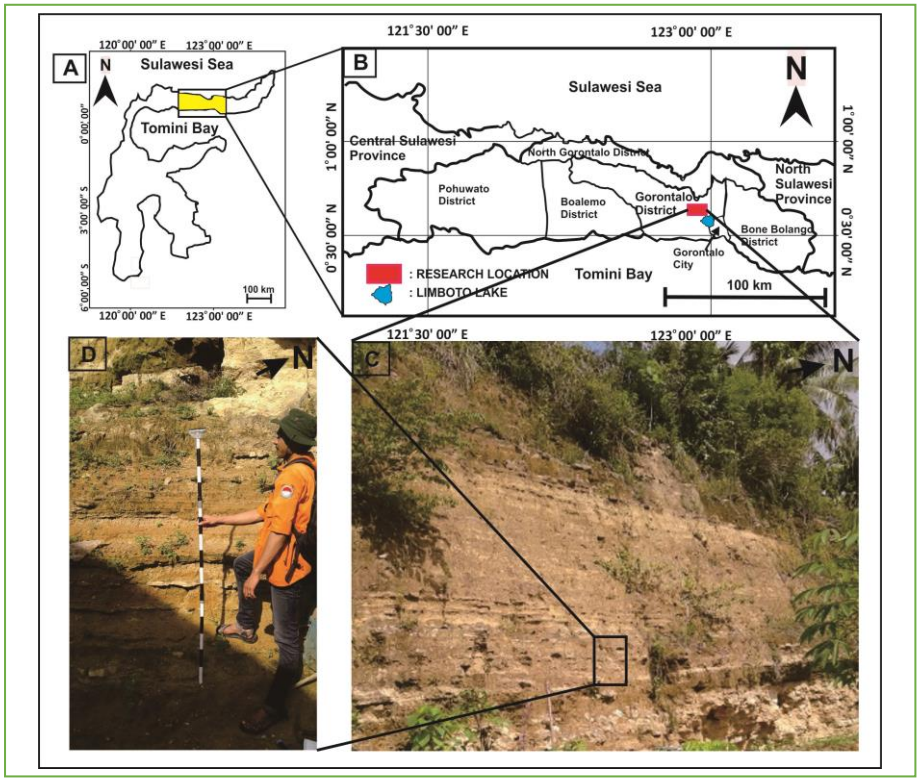

Figure 1. Research location which is located on the north of Lake Limboto, West Limboto District, Gorontalo Regency. (A) the location of Gorontalo Province on the map of Sulawesi island, (B) the research location on the map of Gorontalo Province, (C) the measuring section location on research location, and (D) the measuring section (MS) uses a jacob's staff

3 Research Results and Discussion

C. Facies and Microfacies

MS measurements are carried out in detail by distinguishing one facies unit to another facies. The reference to differentiate these facies is done by doing field descriptions and petrology based on texture, structure, and composition. Determination of standard microfacies (SMF) in addition to the initial data distribution of facies and sedimentary structures found in the field as well as the detailed composition of petrographic analysis. MS results at the research site contain four facies, namely facies A, B, C, and D (Figure 2). Descriptions of the four facies are as follows:

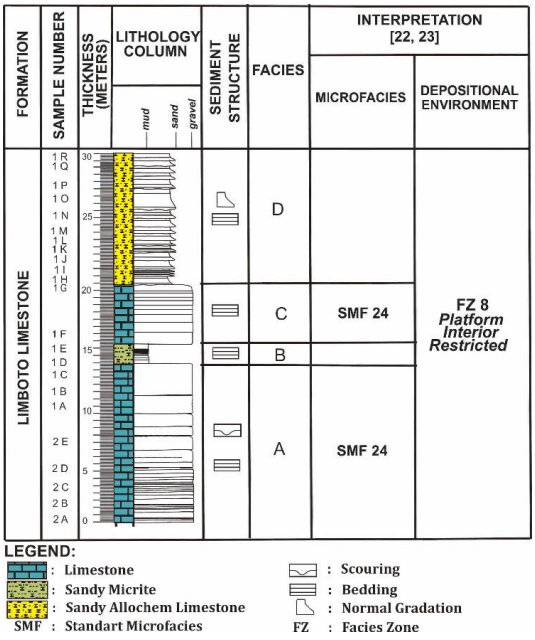

Figure 2. Lithostratigraphic distribution chart which divides Gorontalo limestone into four facies

Facies A is interpreted as coralline rudstone intercalated with thin mudstone facies [16]. The coralline rudstone intercalated with thin mudstone facies are at the bottom of the lithostratigraphic column. The position of this facies is at intervals of 0-13 meters. This facies is described as brownish-white, grain size> 2 mm, poor sorting, rough fragmental bioclastic texture, open packaging, the connection between grain is floating in the matrix. The bedding structure is thickining upward and the scouring structure is at the top of the contact with the mudstone. The rock composition is composed of coral fragments, micrite, and opaque minerals. The composition of these facies based on petrographic analysis consists of red algae (7%), foraminifera (8%), corals (10%), brachiopods (4%), bryozoa (2%), mollusks (1%), echinoids (1%)), and non-skeletal shells in the form of peloids (15%). Granules are embedded in the matrix in the form of carbonate mud (5%) with cementation (30%) in the form of microspar-pseudospar. Found a cavity of vuggy (3%),

intercrystalline (10%), intercrystalline (0.5%), and cracks (0.5%); replacement is characterized by the presence of clay minerals (3%) (Figure 3).

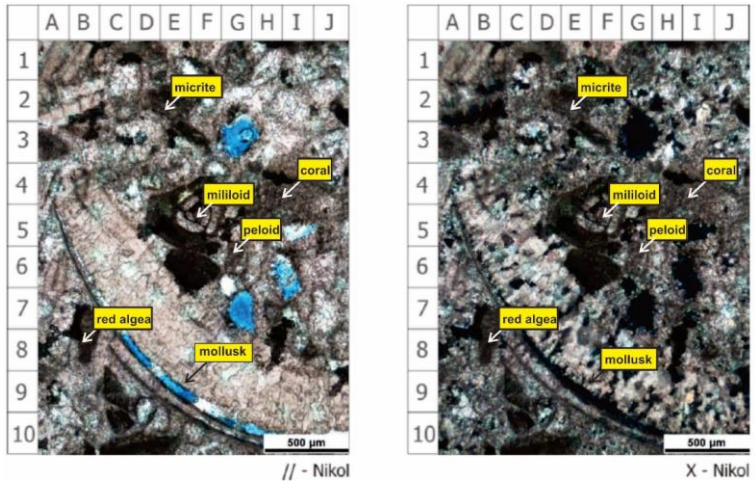

Figure 3. Petrographic analysis of coralline rudstone samples [16], which is Facies A

Based on the composition of these facies, the type of microfacies is SMF 24 [17, 18]. The reason is that these microfacies are composed of coarse bioclasts and are influenced by slope or imbrication with sparse matrices. The depositional environment for microfacies based on the type of SMF 24 is the restricted interior platform (FZ 8) (Figure 4).

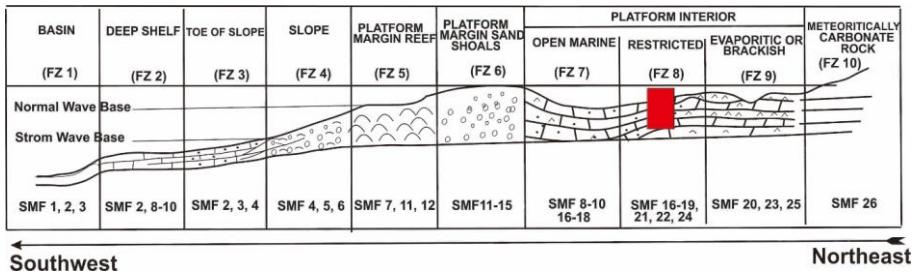

Figure 4. Gorontalo limestone depositional environment, which is a platform interior restricted (FZ 8) [17, 18]

Facies B is interpreted as sandy micrite intercession facies [19]. This facies is above the coralline rudstone intercalated with thin mudstone facies of the lithostratigraphic column. The

position of these facies is at intervals of 13-15 meters. Further, this facies is described as brown, grain-size silt (1/256-1/16 mm), good sorting, closed packaging, composition: micrite and quartz with some rock fragments. The structure of this facies is bedding (thinning upward). The interpretation of depositional energy is high.

The composition of these facies is based on petrographic analysis consisting of small foraminifera (1%), and non-skeletal granules in the form of plagioclase (2%), quartz (3%), hornblende (1%), carbon (7%), opaque minerals (5%), and rock fragments (1%) embedded in the matrix (40%) with cementation (25%) of the cavity in the form of vuggy (5%). Substitution is characterized by the presence of clay minerals (10%) (Figure. 5).

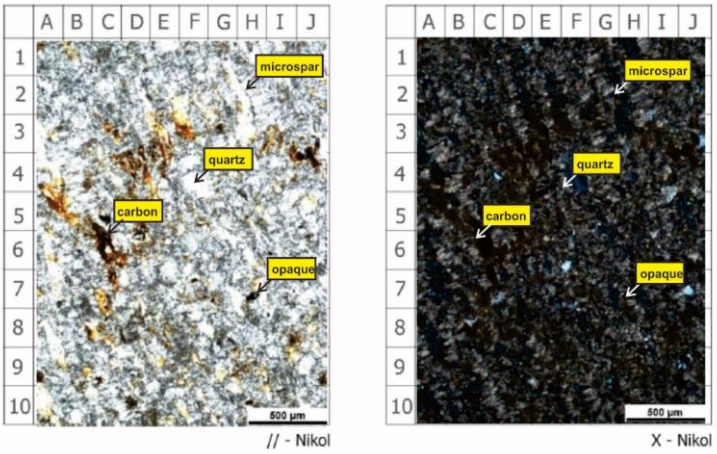

Figure 5. Petrographic analysis of sandy micrite samples [19], which is Facies B

Facies C is interpreted as coralline rudstone intercession facies [16]. The coralline-rudstone intercession facies are above the sandy micrite intercession facies of the lithostratigraphic column. The position of these facies is at intervals of 15-20.5 meters. This facies description is brownish-white, grain size> 2 mm, poor sorting, rough fragmental bioclastic texture, open packaging, the connection between grains is floating in the matrix. The structure is bedding (thinning upward).

Based on the composition of these facies, the type of microfacies is SMF 24 [17, 18]. The reason is that these microfacies are composed of coarse bioclasts and are influenced by slope or imbrication with sparse matrices. The depositional environment for microfacies based on the type of SMF 24 is the restricted interior platform (FZ 8) (Figure 4).

Facies D is interpreted as sandy allochem limestone intercession facies [19]. This facies is above the coralline rudstone intercession facies from the lithostratigraphic column. The position of this facies is at intervals of 20.5-30 meters. This facies description is a light brown, fine-sized grain (1/8-1/4 mm), good sorting, and closed packaging. Further, the structure are bedding (thickining upward) and normal gradation with the composition of the micrite, quartz, and feldspar. The interpretation of formation energy based on grain size is high.

Moreover, the composition of these facies is based on petrographic analysis consisting of small foraminifera (8%), red algae (2%), echinoids (3%), bryozoa (5%), corals (5%), and large

foraminifera (5%). Meanwhile, non-skeletal granules consist of opaque minerals (1%), hornblende (1%), plagioclase (2%), quartz (10%), rock fragments (3%), peloids (7%), carbon (1%)), actinolite (1%) embedded in the matrix (13%) in the form of a small amount of carbonate mud and cementation (7%) in the form of calcite spines and clay minerals (2%). Porosity (25%) is vuggy and moldic (Figure 6).

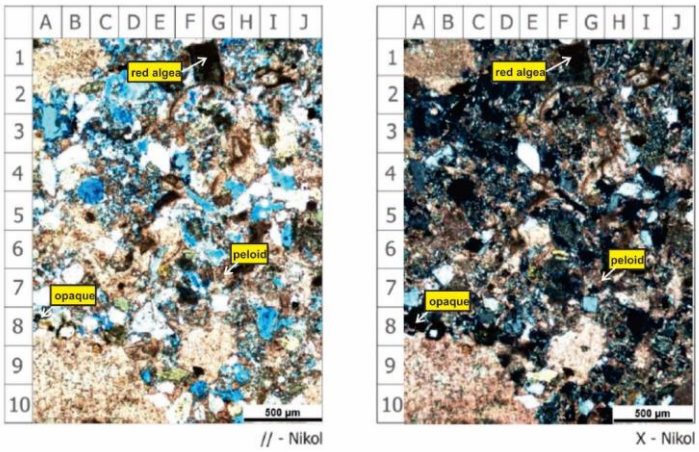

Figure 6. Petrographic analysis of sandy allochem limestone samples [19], which are Facies D

4 Conclusion

The research of microfacies and depositional environments of tertiary limestone, Gorontalo Province, Indonesia yielded several essential points which become the conclusions, including:

5. The facies analysis of tertiary limestone consists of four types of facies, namely coralline rudstone intercalated with thin mudstone facies, sandy micrite intercession facies, coralline rudstone intercession facies and sandy allochem limestone intercession facies.
6. The depositional environment for microfacies based on the type of SMF 24 is the restricted interior platform (FZ 8).

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MICROFACIES AND DEPOSITIONAL ENVIRONMENT OF TERTIARY LIMESTONE, GORONTALO PROVINCE, INDONESIA

Abstract. The research area is located in northern Limboto Lake in Gorontalo Province, which has complex geological characteristics. The geological complexities include stratigraphy and tectonics which influence the formation of the Limboto Basin. Limestone research in the Late Tertiary Limboto Basin is very intriguing to be done because of the lack of research in limestone. Gorontalo limestone outcrops, which become the focus of the research, have a total thickness of 30 meters. The research objective is to analyze facies, microfacies, and depositional environment of tertiary limestone. These two research objectives are attained by using two research methods, namely measurd section and petrography analysis. The research result exhibits that there are four Gorontalo limestones facies, including coralline rudstone intercalated with thin mudstone facies, sandy micrite intercession facies, coralline rudstone intercession facies and sandy allochem limestone intercession facies. According to the limestone microfacies standard, the depositional environment of Gorontalo limestone is platform interior restricted (facies zone 8).

Keywords: microfacies, depositional environment, tertiary limestone, Gorontalo.

Introduction. Sulawesi Island has tectonic and geological complexity. This complexity is influenced by the collision of three plates, namely the Eurasian Plate, the Indo-Australian Plate, and the Pacific Plate. The interaction of these three plates causes a striking change from the shape of the Sulawesi island, changing from an archipelago with a convex side towards the Pacific Ocean to the K shape as it is now. The collision of the moving Pacific plate pushes Sulawesi westward along 800 km [1, 2].

Sulawesi complexity makes this island, can be divided into several tectonic provinces including pluton and volcanic rocks composing the West Sulawesi arm, the metamorphic belt composing Central Sulawesi, ophiolites composing East Sulawesi and the continental micro blocks of Banggai-Sula and Buton-Tukang Besi [3, 4].

The north arm of Sulawesi, which is part of the West Sulawesi arm, is also composed of volcanic rock, which is estimated to be of late Paleogene and Neogene origin from the Maluku plate and Sulawesi Sea plate subduction zone [5]. The middle part of the Sulawesi North Arm lies the Limboto plain formed by Limboto Lake and several rivers. The constituent rocks in this basin are limestone. Quaternary limestone spread to the northwest of Lake Limboto with an area of 20 x 4 km2 of Pliocene-Pleistocene age and in the west and south an area of 37 x 4 km2 of Pleistocene age [6, 7].

The distribution of Quaternary age rocks is closely related to the various forms of morphology and basin shapes produced by the last tectonic process which developed since the time of the Late Miocene epoch, volcanic activity, and denudation processes. Quaternary rock distribution can be known from remote sensing imagery, both with aerial portraits, radar, and Landsat. The alluvial plateau and elevated coral limestone that spread out wide shows the stability of the bedrocks [7, 8].

Limestone research in Lake Limboto has been done by creating a regional geological map. Two limestone formations consist of Clastic Limestone Formation and Coral Limestone Formation. The Pliocene-Pleistocene Clastic Limestone Formation is located in the west of the lake comprising calcarenite, calcirudite and coral limestone with the thickness up to 200 meters. Coral Limestone Formation (Ql)

which is located in the south of the lake is estimated to be Holocene; this reef limestone is uplifted with the main component of coral [9].

Limestone research in Limboto Lake has only been carried out in general by producing regional geological maps. Two limestone formations are Clastic Limestone Formation and Reef Limestone Formation. The Clastic Limestone Formation located in the western lake is Pliocene-Pleistocene lake with calcarenite lithology, calcirudite and coral limestone with thickness up to 200 meters. The Reef Limestone Formation (Ql) found in the south of the lake is estimated to be Holocene in age; this reef limestone is elevated with coral as the main component [9].

Limestone research in the Yosonegoro area produces two facies and microfacies, namely coraline rudstone facies and wackestone-packestone intercession facies with a slope to toe of slope depositional environment [10]. Limestone research in the north of Lake Limboto is carried out due to a lack of research data on Gorontalo limestone. Hence, this research is carried out in detail by taking a more comprehensive approach from the geological aspect so that new findings will be generated. The research aims to analyze microfacies, depositional environments, relative age and paleobathymetry of Gorontalo limestone, which involves microfacies and biostratigraphy analysis methods.

Research Method. The location of the research is the West Limboto District of Gorontalo Regency in the North of Lake Limboto with the geographical location at coordinates (00º 39' 5"- 00º 39' 7.644" North) and (122º 55' 20.833"- 122º 55' 34" East) (figure 1). Materials and research supplies are limestone outcrops with a thickness of up to 30 meters. The research method consists of two stages. The first stage is doing a measured section (MS) using a 1.5 meter interval jacob's staff systematically from the oldest to the youngest rocks [10, 11, 12, 13].

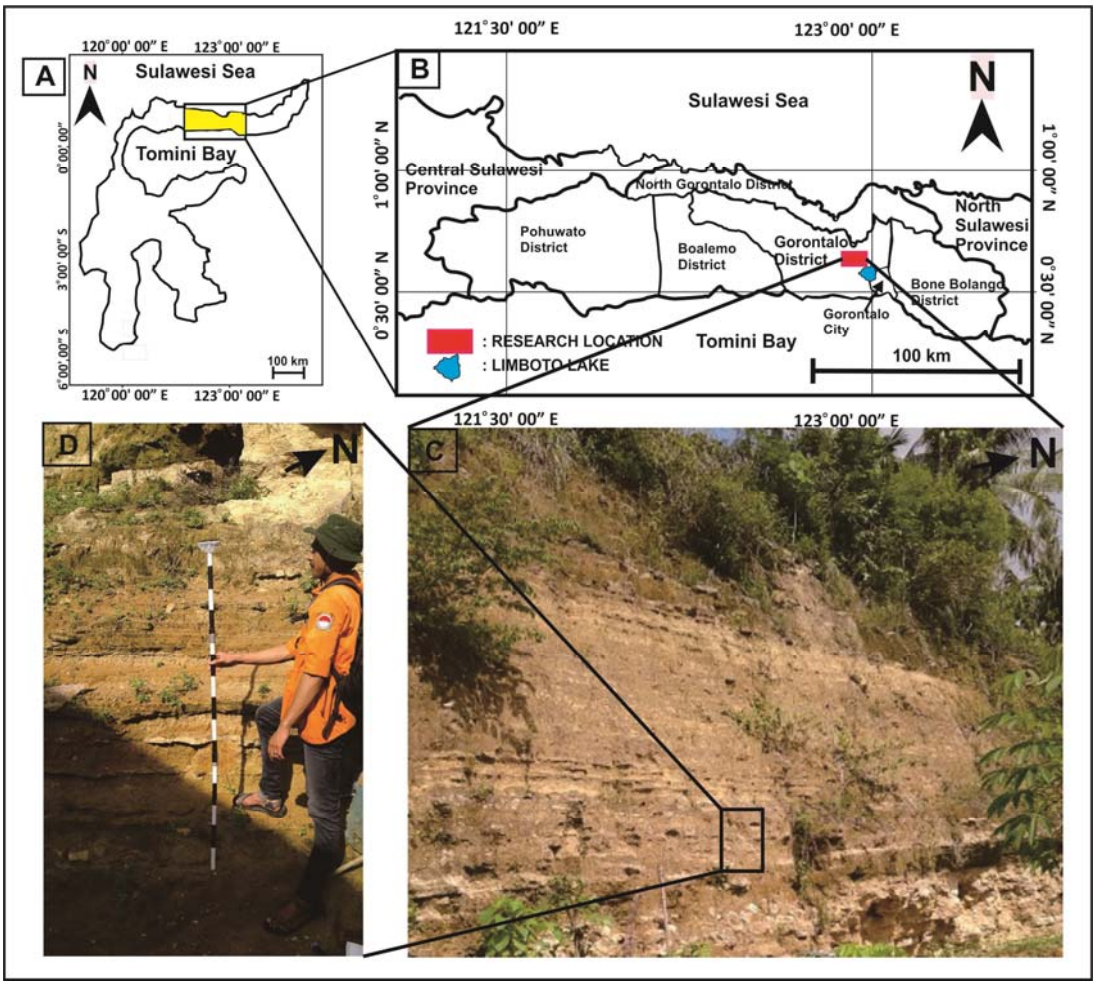

Figure 1 – Research location which is located on the north of Lake Limboto, West Limboto District, Gorontalo Regency. (A) the location of Gorontalo Province on the map of Sulawesi island, (B) the research location on the map of Gorontalo Province, (C) the measuring section location on research location, and (D) the measuring section (MS) uses a jacob's staff

This method is fundamental to know the facies in the study site, including measuring the exact thickness of the facies and taking appropriate samples for petrographic analysis. The next method is the petrographic analysis of a thin section using a 1053 polarization microscope equipped with a computer-connected camera. The petrographic analysis is beneficial in determining microfacies so that the depositional environment can be easily determined [14, 15].

Research Results and Discussion.

A. Facies and Microfacies. MS measurements are carried out in detail by distinguishing one facies unit to another facies. The reference to differentiate these facies is done by doing field descriptions and petrology based on texture, structure, and composition. Determination of standard microfacies (SMF) in addition to the initial data distribution of facies and sedimentary structures found in the field as well as the detailed composition of petrographic analysis. MS results at the research site contain four facies, namely facies A, B, C, and D (figure 2). Descriptions of the four facies are as follows:

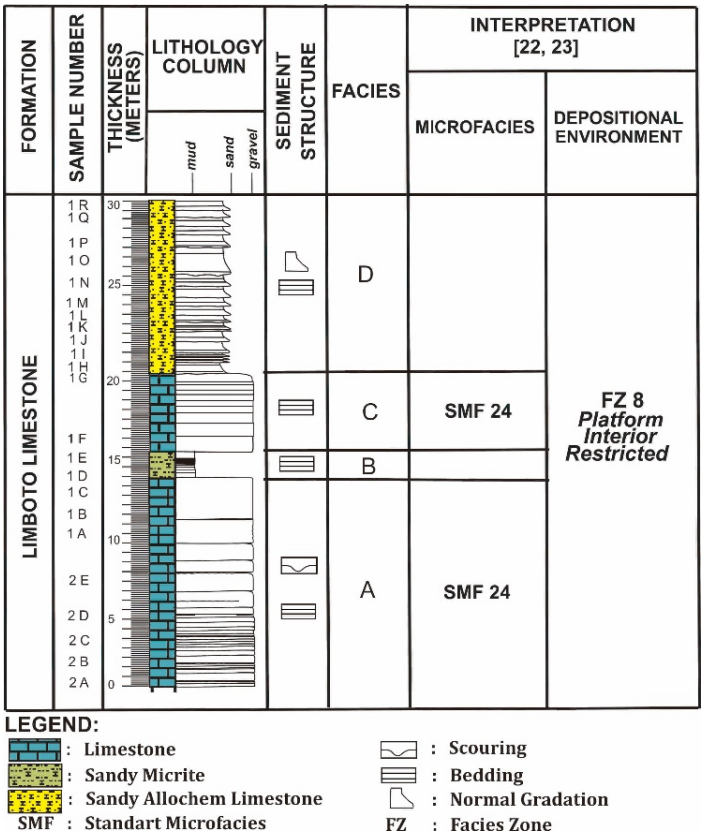

Figure 2 – Lithostratigraphic distribution chart which divides Gorontalo limestone into four facies

Facies A is interpreted as coralline rudstone intercalated with thin mudstone facies [16]. The coralline rudstone intercalated with thin mudstone facies are at the bottom of the lithostratigraphic column. The position of this facies is at intervals of 0-13 meters. This facies is described as brownish-white, grain size> 2 mm, poor sorting, rough fragmental bioclastic texture, open packaging, the connection between grain is floating in the matrix. The bedding structure is thickining upward and the scouring structure is at the top of the contact with the mudstone. The rock composition is composed of coral fragments, micrite, and opaque minerals. The composition of these facies based on petrographic analysis consists of red algae (7%), foraminifera (8%), corals (10%), brachiopods (4%), bryozoa (2%), mollusks (1%), echinoids (1%)), and non-skeletal shells in the form of peloids (15%). Granules are embedded in the matrix in the form of carbonate mud (5%) with cementation (30%) in the form of microspar-pseudospar. Found a cavity of vuggy (3%), intercrystalline (10%), intercrystalline (0.5%), and cracks (0.5%); replacement is characterized by the presence of clay minerals (3%) (figure 3).

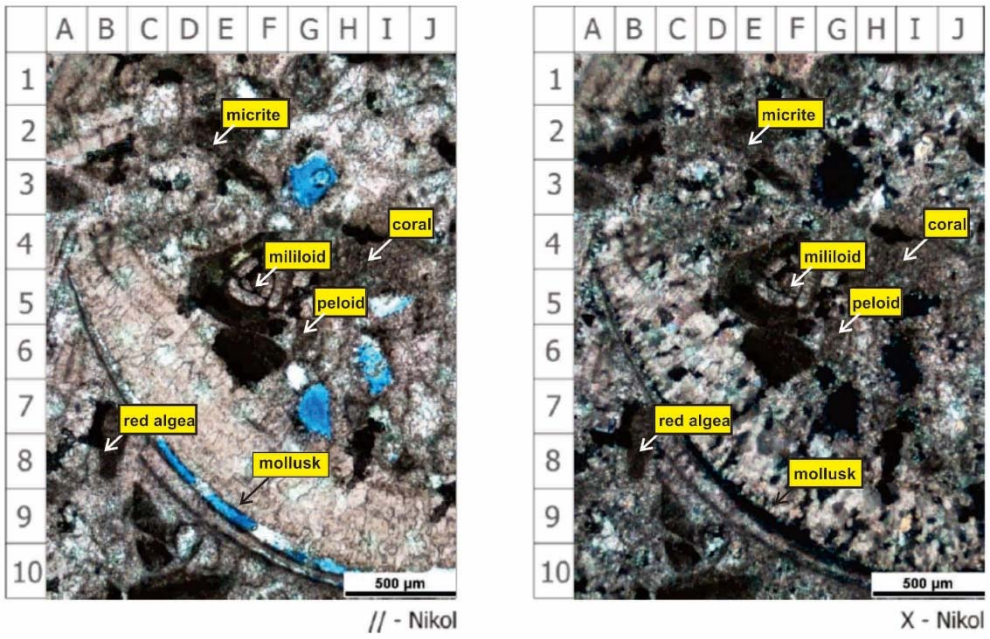

Figure 3 – Petrographic analysis of coralline rudstone samples [16], which is Facies A

Based on the composition of these facies, the type of microfacies is SMF 24 [17, 18]. The reason is that these microfacies are composed of coarse bioclasts and are influenced by slope or imbrication with sparse matrices. The depositional environment for microfacies based on the type of SMF 24 is the restricted interior platform (FZ 8) (figure 4).

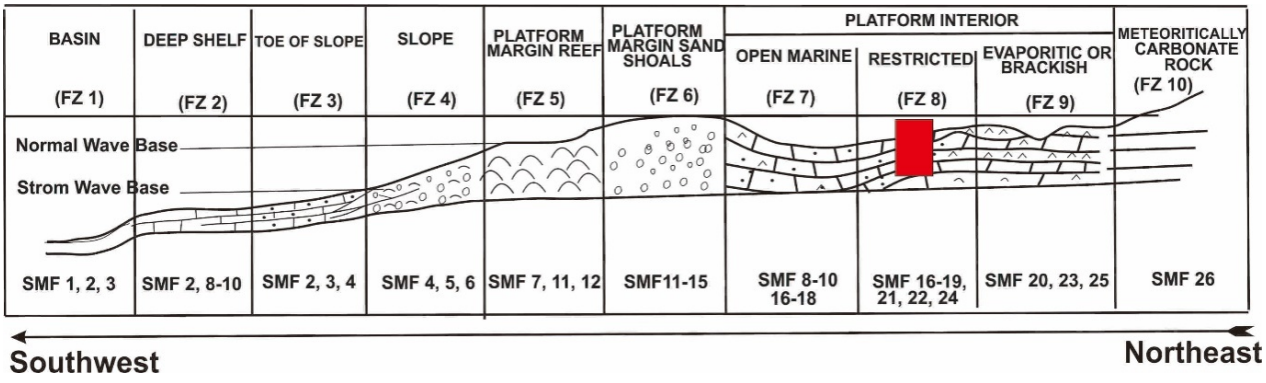

Figure 4 – Gorontalo limestone depositional environment,
which is a platform interior restricted (FZ 8) [17, 18]

Facies B is interpreted as sandy micrite intercession facies [19]. This facies is above the coralline rudstone intercalated with thin mudstone facies of the lithostratigraphic column. The position of these facies is at intervals of 13-15 meters. Further, this facies is described as brown, grain-size silt (1/256-1/16 mm), good sorting, closed packaging, composition: micrite and quartz with some rock fragments. The structure of this facies is bedding (thinning upward). The interpretation of depositional energy is high.

The composition of these facies is based on petrographic analysis consisting of small foraminifera (1%), and non-skeletal granules in the form of plagioclase (2%), quartz (3%), hornblende (1%), carbon (7%), opaque minerals (5%), and rock fragments (1%) embedded in the matrix (40%) with cementation (25%) of the cavity in the form of vuggy (5%). Substitution is characterized by the presence of clay minerals (10%) (figure. 5).

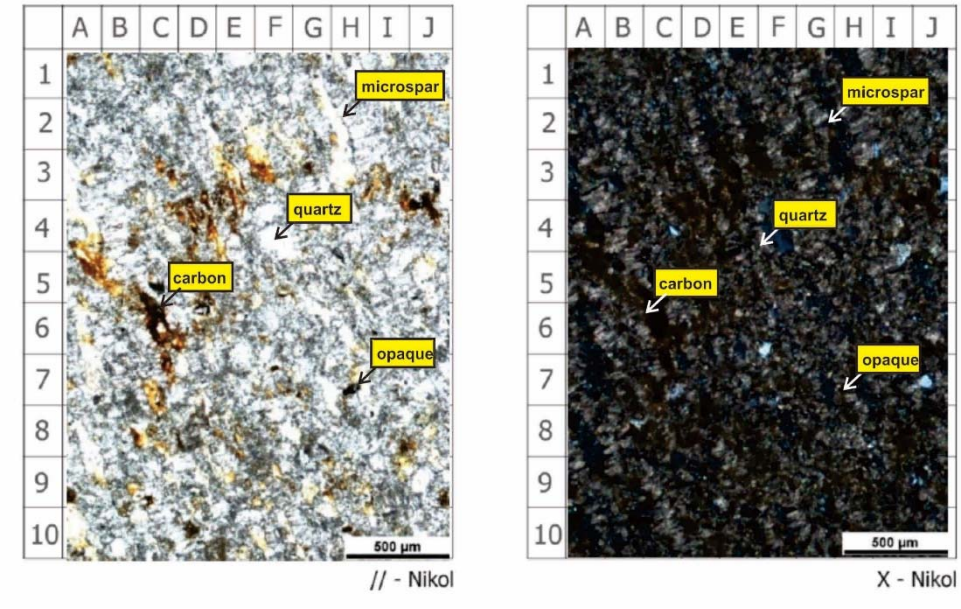

Figure 5 – Petrographic analysis of sandy micrite samples [19], which is Facies B

Facies C is interpreted as coralline rudstone intercession facies [16]. The coralline-rudstone intercession facies are above the sandy micrite intercession facies of the lithostratigraphic column. The position of these facies is at intervals of 15-20.5 meters. This facies description is brownish-white, grain size > 2 mm, poor sorting, rough fragmental bioclastic texture, open packaging, the connection between grains is floating in the matrix. The structure is bedding (thinning upward).

Based on the composition of these facies, the type of microfacies is SMF 24 [17, 18]. The reason is that these microfacies are composed of coarse bioclasts and are influenced by slope or imbrication with sparse matrices. The depositional environment for microfacies based on the type of SMF 24 is the restricted interior platform (FZ 8) (figure 4).

Facies D is interpreted as sandy allochem limestone intercession facies [19]. This facies are above the coralline rudstone intercession facies from the lithostratigraphic column. The position of this facies is at intervals of 20.5-30 meters. This facies description is a light brown, fine-sized grain (1/8-1/4 mm), good sorting, and closed packaging. Further, the structure is bedding (thickining upward) and normal gradation

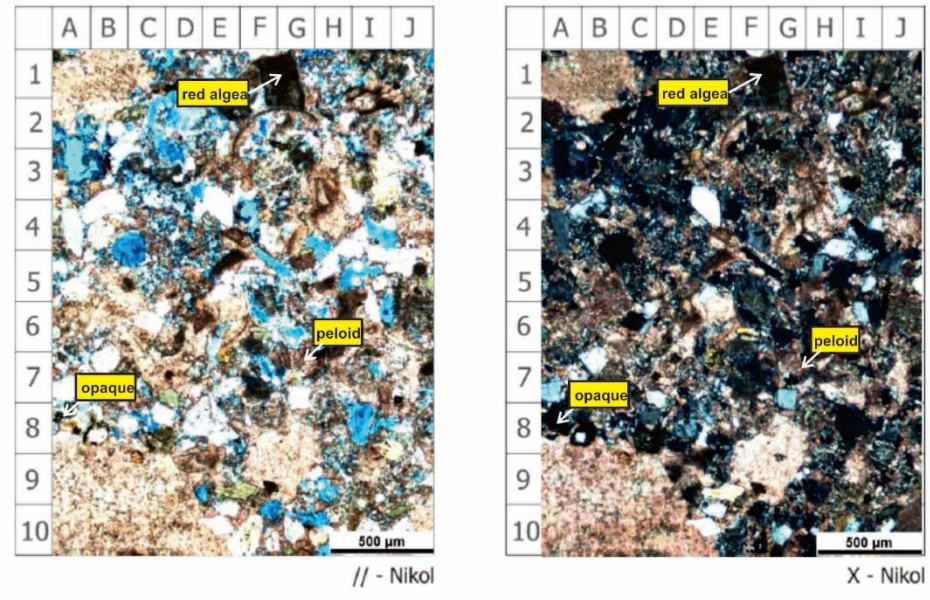

Figure 6 – Petrographic analysis of sandy allochem limestone samples [19], which are Facies D

with the composition of the micrite, quartz, and feldspar. The interpretation of formation energy based on grain size is high.

Moreover, the composition of these facies is based on petrographic analysis consisting of small foraminifera (8%), red algae (2%), echinoids (3%), bryozoa (5%), corals (5%), and large foraminifera (5%). Meanwhile, non-skeletal granules consist of opaque minerals (1%), hornblende (1%), plagioclase (2%), quartz (10%), rock fragments (3%), peloids (7%), carbon (1%), actinolite (1%) embedded in the matrix (13%) in the form of a small amount of carbonate mud and cementation (7%) in the form of calcite spines and clay minerals (2%). Porosity (25%) is vuggy and moldic (figure 6).

Conclusion. The research of microfacies and depositional environments of tertiary limestone, Gorontalo Province, Indonesia yielded several essential points which become the conclusions, including:

1. The facies analysis of tertiary limestone consists of four types of facies, namely coralline rudstone intercalated with thin mudstone facies, sandy micrite intercession facies, coralline rudstone intercession facies and sandy allochem limestone intercession facies.

2. The depositional environment for microfacies based on the type of SMF 24 is the restricted interior platform (FZ 8).

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МИКРОФАЦИАЛЬНАЯ И ОСАДОЧНАЯ СРЕДА ТРЕТИЧНОГО ИЗВЕСТНЯКА, ПРОВИНЦИЯ ГОРОНТАЛО, ИНДОНЕЗИЯ

Аннотация. Район исследований расположен в северном озере Лимбото в провинции Горонтало, которое имеет сложные геологические характеристики. Геологические сложности включают стратиграфию и тектонику, которые влияют на формирование бассейна Лимбото. Исследования известняка в позднетретичном бассейне Лимбото очень интересны из-за отсутствия до сих пор исследований по известняку. Горонтальские известняковые обнажения, ставшие объектом исследования, имеют общую толщину 30 метров. Цель исследования – анализ фациальной, микрофациальной и осадочной среды третичных известняков. Эти две цели исследования достигаются с помощью двух методов исследования, а именно измерительного разреза и петрографического анализа. Результаты исследований показывают, что существует четыре фации горонтало-известняков, в том числе коралловый рудный камень, интеркалированный тонкими аргиллитными фациями, песчаная микритная покровная фация, коралловая рудная покровная фация и песчаная аллохимическая известняковая покровная фация. Согласно стандарту микрофаций известняка, осадочная среда горонтальского известняка ограничена внутри платформы (фациальная зона 8).

Ключевые слова: микрофации, осадочная среда, третичный известняк, Горонтало.

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