ANALYSIS OF MICROFACIES AND DEPOSITIONAL ENVIRONMENT OF LIMESTONE IN YOSONEGORO AREA, GORONTALO (INDONESIA)

by Aang Panji Permana

ANALYSIS OF MICROFACIES AND DEPOSITIONAL ENVIRONMENT OF LIMESTONE IN YOSONEGORO AREA, GORONTALO (INDONESIA)

Aang Panji Permana*, Subagyo Pramumijoyo**, Akmaluddin**

Abstract

The research location is situated in the northern part of Lake Limboto Basin, Gorontalo Province. This research focuses on 24 meters limestone outcrops. The objectives of the study were to find out facies, standard microfacies (SMF) and depositional environments of Limboto limestones. There are three methods utilized in this research such as the measured section (MS), petrographical analysis and biostratigraphical analysis. The limestone facies in the Yosonegoro Gorontalo area consists of two facies distinguished by its sedimentary structure, composition, color, depositional texture, terrigenous components and bioclasts. Moreover, these two facies are divided into three different microfacies. Paleobathymetry shows a deepening trend due to the sea level rise from the middle shelf-upper slope to the upper slope-lower slope. The compilation of SMF and paleobathymetry types indicates changes in the depositional environment from slope (FZ 4) environments to the toe of slope (FZ 3) environment. This finding has led researchers to propose a new formation name called as the Limboto Limestone Formation that was previously known as Clastic Limestone Formation based on its distinctive characteristics.

Keywords: Gorontalo, Microfacies, Depositional Environment

INTRODUCTION. Sulawesi Island with the unique K-shape physiography is situated in Indonesian territory as a result of interaction and collision among the Eurasian plate, Indian-Australian plate and the Pacific plate. Based on the physiography, Sulawesi Island comprises the south arm, the middle part, the north arm, the east arm, the southern arm and the neck. This condition makes Sulawesi has several geological provinces [1–4].

The limestone distribution is on the North Arm of Sulawesi right in the Lake Limboto basin which has a width of 35 km^2. The middle basin was formed by several river valleys such as Paguat, Randangan, Dumoga Ongkang, Paguyaman, Bone and Lake Limboto. This basin is often referred to as the Limboto zone which is continuous to Minahasa (Lake Tondano) [5]. Tectonic influences are very strong, particularly from the position of Quarternary reef limestones in the Gorontalo region. This reef limestone underwent a very strong uplifting proven by the obtained field data from Gorontalo and the northern coast of Tanjung Daka which reaches a height of more than 1,000 meters [6].

Geological Setting. The distribution of limestone in the western and northern part of Lake Limboto comprises the Pliocene-Pleistocene Clastic Limestone Formation (TQl). Limestone found as calcarenite and calcirudite are usually associated with the white coral limestone. This limestone contains fragments of algae fossils and molluscs (Fig. 1). This formation spreads with thicknesses varying from 100 - 200 meters [7].

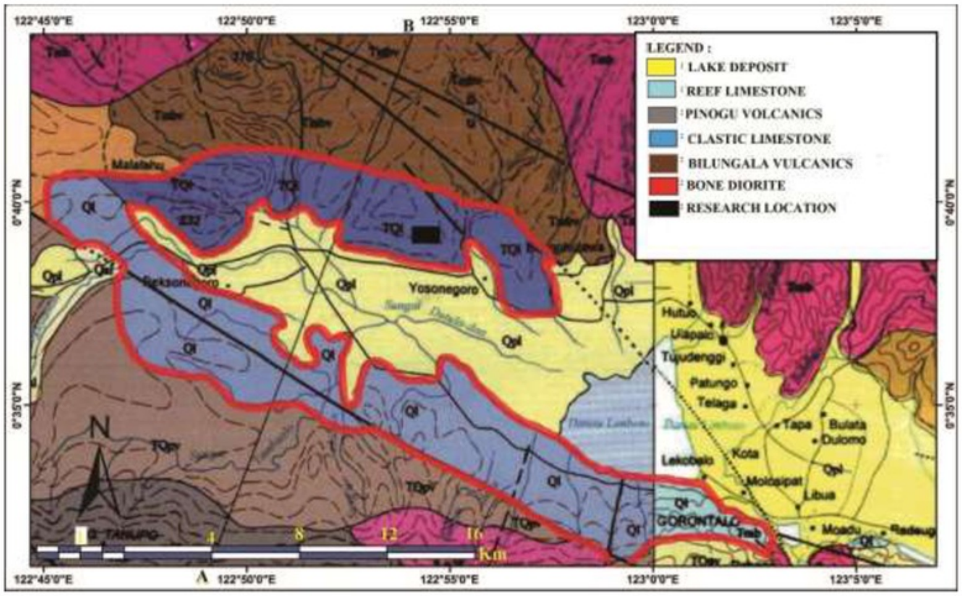
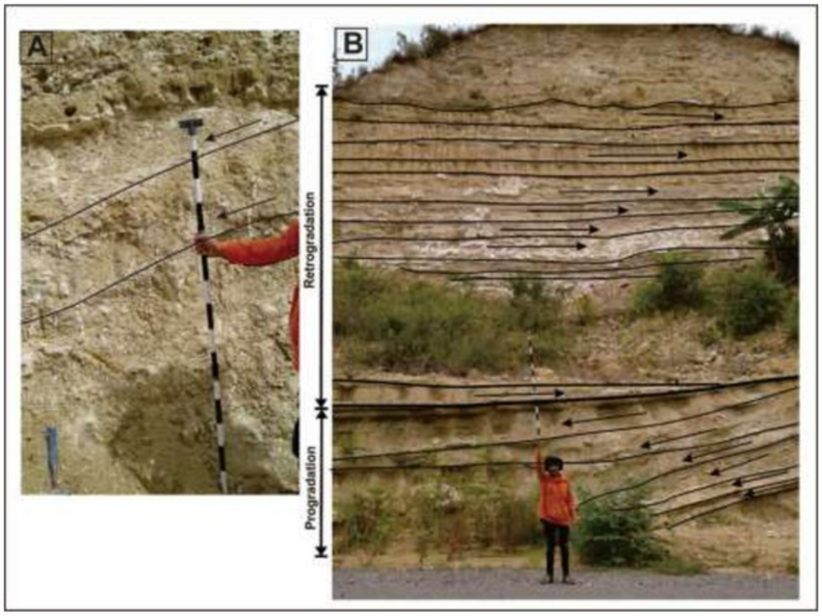


Figure 1. Regional geology of the research area in the Lake Limboto basin [7]

Detail research on limestone related to facies, microfacies and depositional environments has never been done, so this research is interesting and challenging because the available data are only from the regional literature. Three research objectives will be achieved, such as recognizing the microfacies, paleobathymetry and depositional environment within the study area.

Material and methods. The research location is located in Yosonegoro Gorontalo district, or in the northern part of the Lake Limboto Basin Gorontalo geographically located at coordinates of (00° 39' 6.7222" North, 122° 54' 50.0385" East) to (00° 39' 6.9397" North, 122° 54' 57.5275" East). Research material is emphasized on the 24 meters of limestone outcrop. The methods used in this research are the measured section (MS), petrographical analysis and biostratigraphical analysis. The MS method is utilized to do a detailed measurement of bedding by using a Jacob's staff in the 1.5-meter interval with sequential and systematic lithology sampling [8]. Petrographical analysis uses the Euromex 1053 polarization microscope. Thin sections of Limestones are made using the blocking method to impregnate the blue solution into the pore to distinguish the original pores of the rock from the formed pore during preparation [9–10]. The biostratigraphical analysis uses the Olympus SZ61 binocular microscope. Biostratigraphical analysis can be used to identify the type of benthonic foraminifera fossils [11–13].

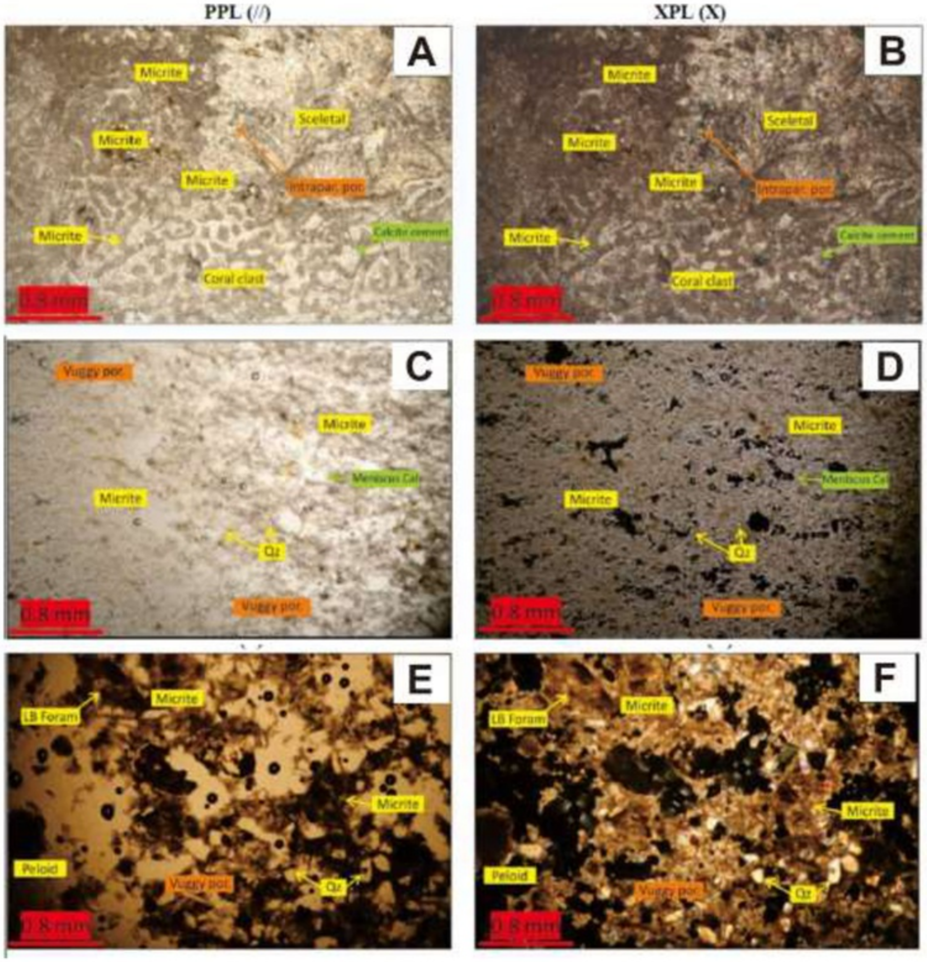
Result. Facies and Microfacies. MS measurements at the study area show two limestone facies that could be distinguished from the physical characteristics of texture, structure and composition. Facies A is coralline rudstone facies [14]. This facies is distributed in the lowest interval at a thickness of 0 - 9.2 meters. Its constituent characteristics are coral fragments, rock fragments and quartz non-carbonate grains. The structure of this facies is thinning upward and thinning to the southwest. The energy interpretation of the formation based on the grain size is high. The facies depositional pattern referring to the position of relative sea level drop [15] is progradation (a depositional pattern that fills the accommodation in front of it) due to the effect of the greater sediment supply in comparison with the accommodation space (Figure 2A).



Picture 2 . The depositional pattern of two different facies. (A) The coralline rudstone facies has a progradation depositional pattern. (B) Mudstone-sparse biomicrite intercession facies depositional pattern which is initially progradation changed into retrogradation

Facies B are interbedded mudstone facies with sparse biomicrite [16-17]. This facies is at the topmost part having a thickness of 9.2 - 24 meters. Mudstone of this facies is dominantly composed of micrite with its thickning upward structure. As for the sparse biomicrite, it is characterized by the large foraminifera, peloid, extraclast, quartz, micrite, and sparite. The bedding structure is characterized by thining upward structure and scouring at the upper boundary of contact with mudstone. The interpretation of depositional energy in this facies is lowering upward, which means that the deposited sediment is chiefly finer material. The depositional pattern is initially progradation then it gradually changes into retrogradation deposition pattern in the upper part (backstepping occurs). This progradation is due to the relative sea level rise, a condition when the sediment supply is lower than the accommodation space. Changes in the sedimentation patterns are supported by the decreasing of sloping angle from 35^o to 10^o (Figure 2B).

The division of two limestone facies and sedimentary structures is used for the initial data to determine the standard type of microfacies (SMF). 24 types of SMF were proposed on the basis of the main types of carbonate grain, paleontological data, an abundance of micrites and carbonate fabric [18]. 24 types of SMF [18] used the texture classifications of [16] and modified [14]. However, there were two additional types of new SMF, called SMF 25 and 26, so there are a total of 26 types of SMF [19]. There are three microfacies that can be interpreted from the two facies units that exist, among others reef rudstone microfacies and pelagic mudstone microfacies-microbreccia microfacies.



Picture 3. Petrographical analysis (A-B) of reef rudstone microfacies in sample 3A, (C-D) pelagic mudstone microfacies in the 3G sample and (E-F) microbreccia microfacies in the 3F sample

Coralline rudstone facies based on petrographical analysis and field data is interpreted to be reef rudstone microfacies (type SMF 6) (Figure 3A-B). The reason is the main constituent of these microfacies is a large bioclast from reef coral [18-19].

The interbedded mudstone facies with sparse biomicrite facies has two microfacies, called as pelagic mudstone microfacies (SMF 3) and microbreccia microfacies (SMF 4). The interpretation of pelagic mudstone microfacies is done on the basis of the mudstone characteristics which are mainly composed of 95% micrite (Figure 3C-3D). Whereas, the interpretation of microbreccia microfacies is based on the sparse biomicrite characterized by reworked materials such as quartz minerals and carbonate rock fragments (Figure 3E-3F) [18-19].

Paleobathymetry. Paleobathymetry becomes an important data to support the interpretation of depositional environments other than SMF type. Paleobathymetry can be seen from the biostratigraphic analysis, especially an assemblage of benthic fossils, with a total of six analyzed samples. Benthic fossils in the reef rudstone microfacies are represented in sample 3B consisting of *Cornuspira foliacea* (Philippi, 1844), *Fijinonion phiense* (Cushman & Edwards, 1937), *Melonis affinis* (Reuss, 1851), *Nonion fabum* (Fichtel & Moll, 1798) and *Rhabdammina discreata* (Brady, 1881). The occurrence of five benthonic fossils species indicates a middle self - upper slope zone at a depth of 73.2 - 283.65 meters [20-21].

The benthic fossils in the pelagic mudstone microfacies-microbreccia microfacies are represented by samples 3E, 3G, 3H, 3I and 3J consisting of *Fijinonion phiense*

(Cushman & Edwards, 1937), *Gyrodinoides soldanii* (d'Orbigny, 1825), *Nonion fabum* (Fichtel & Moll, 1798), *Praeglobobulimina ovata* (d'Orbigny, 1846), *Rhabdammina discreata* (Brady, 1881) and *Saccorhiza ramosa* (Brady, 1879). The interpretation of these six benthonic fossil species occurrence shows an increasing depth of paleobathymetry. The paleobathymetry of sample 3E shows an outer shelf-upper slope zone with a depth of 183-366 meters. Samples 3G is in the upper slope zone with a depth of 283.65-366 meters. The sample 3H is in the upper slope-lower slope zone with a depth of 283.65-1,830 meters. Sample 3I is in the upper slope-lower slope zone with a depth of 283.65-1,830 meters. Finally, sample 3J shows an upper slope zone with a depth of 283.65-466.65 meters [20–21]. The paleobathymetry sequence from bottom to top can be seen in Figure 4.

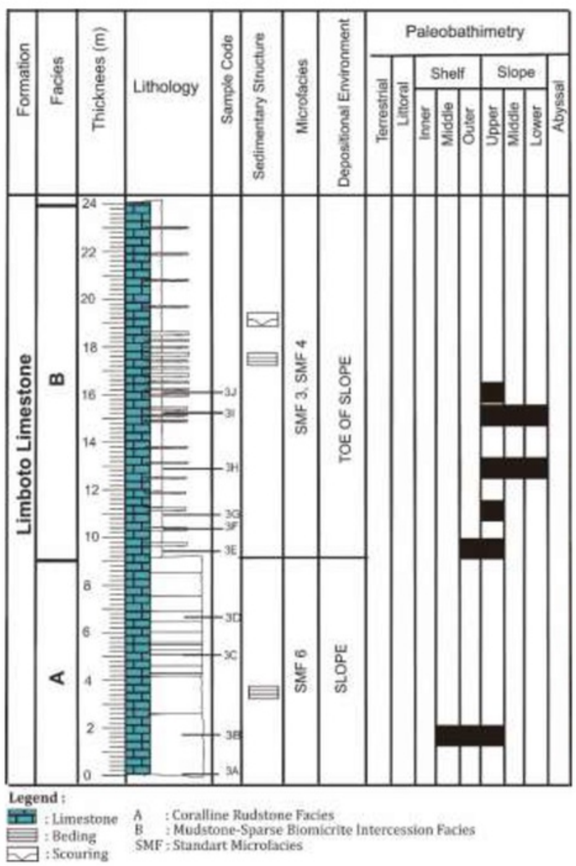
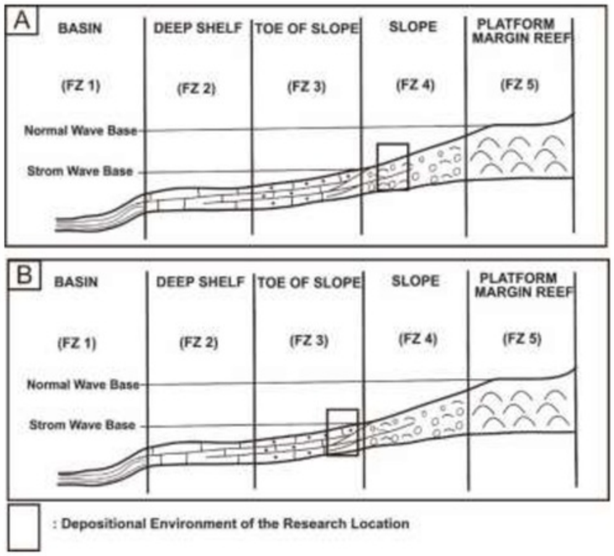


Figure 4. Chart of facies distribution, standard microfacies (SMF), depositional environment [18-19] and paleobathymetry [20–21].

Deposition Environment. The depositional environment interpretation or facies zone (FZ) of the study area was determined from the compilation of SMF type, and paleobathymetry identified using the classification of [18-19]. The depositional environment for reef rudstone microfacies (SMF 6) with paleobathymetry middle shelf-upper slope is a slope environment (FZ 4).

The depositional environment of pelagic mudstone microfacies (SMF 3) and microbreccia microfacies (SMF 4) with paleobathymetry upper slope-lower slope occurred on the toe of slope (FZ 3) environment (Figure 5). The depositional history in the study area was preceded by the deposition of reef rudstone microfacies in the slope area and then deposited contemporaneously with pelagic mudstone microfacies and microbreccia microfacies in the toe of slope environment (Figure 5).



Picture 5 Interpretation of the depositional environment of the study area (A) Depositional environment of reef rudstone microfacies on the slope. (B) Depositional environment of pelagic mudstone microfacies and microbrecia microfacies on the toe of slope [18–19].

Conclusion. The limestone facies of the Yosonegoro area, Gorontalo Limboto Lake Basin consists of two coralline rudstone facies and mudstone facies with sparse biomicrite facies. Coralline rudstone facies are determined by the sedimentary structure, composition, color, depositional texture, terrigenous components and bioclast according to the reef rudstone microfacies (SMF 6) type. The interbedded mudstone facies with sparse biomicrite have the same characteristics as the pelagic mudstone microfacies and microbreccia microfacies (SMF 3 and 4). Paleobathymetry shows an increasing depth due to the sea level rise from the middle shelf-upper slope to the upper slope-lower slope. The compilation of SMF type and paleobathymetry shows changes in the depositional environment. The reef rudstone microfacies was deposited in the slope (FZ 4) depositional environment then the pelagic mudstone microfacies and microbrecia microfacies were contemporaneously deposited in the toe of slope (FZ 3) environment. This finding led researchers to propose a name of the new formation called the Limboto Limestone Formation according to the characteristic of the name of the previous formation of the Clastic Limestone Formation [7].

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REFERENCES

[1] HAMILTON W. (1979) Tectonics of the Indonesian region. Geological Survey Professional Paper 1078, U.S. Govern. Printing Office, Washington. U.S.G.S. Professional Paper 1078. Pp 345.

[2] HUTCHISON C., S. (1989) Geological evolution of Southeast Asia. Oxford Monograph on Geology and Geophysicc no 13, Oxford. Pp 368.

[3] SUKAMTO R. SIMANDJUNTAK T., O. (1983) Tectonic relationship between geologic province of Western Sulawesi, Eastern Sulawesi and Banggai-Sula in the light of sedimentological aspect, Bulletin Geological Research and Development Centre Bandung, **7**: 1-12.

[4] KATILI J., A. (1978) Past and present geotectonic position of Sulawesi, Indonesia. In: S.Uyeda (editor), Active Plate Boundaries of the Western Pacific. Tectonophysics, **45**: 289-322.

[5] VAN BEMMELEN R., W. (1949) The Geology of Indonesia Vol 1A. Government Printing Office The Hauge. p. 732.

[6] KATILI J., A. (1970) Large transcurrent faults in Southeast Asia with special reference to Indonesia. International Journal of earth Science, (59), Issue **2** : 581–600.

[7] BACHRI S. PARTOYO E. BAWONO S., S. SUKARNA D. SURONO. SUPANDJONO J., B. (1997) Regional Geology of Gorontalo, North Sulawesi. Collection of Research and Mapping Results Papers Centre for Geological Research and Development : 18-30.

[8] COMPTON R., R. (1985) Geology in the field. New York : Wiley Press. p. 416.

[9] DICKSON J., A., D. (1966) Carbonate identification and genesis revealed by staning. Sedimentary Petrology Journal, Vol 36 **(2)** : 491-505.

[10] CRABTREE S., J. EHRLIG R. Prince C. (1984) Evaluation of strategies for segmentation of blue-dyed pores in thin sections of reservoir rocks. Computer vision, graphics and image processing, No 28 : 1-18.

[11] NICHOLS G. (2009) Sedimentology and stratigraphy. London : Blackwell Science Ltd. 335 p.

[12]ROOZPEYKAR A. MOGHADDAM I., M. (2016) Benthic foraminifera as biostratigrpahical and paleoecological indicators : an example from Oligo-Miocene deposits in the SW of Zagros Basin, Iran, Geoscience Frontiers 7 : 125-140.

[13] OLADIMEJI A. ADEYINKA S., A. ADEKEYE O., A. OLESEGUM O. EMMANUEL O., F. (2017) Foraminifera biostratrigraphy and depositional environment of sediment in sile well Offshore Dahomey Basin Benin Republlic, Mayfeb Journal of Enviromental Science, (Vol 1) : 18-33.

[14] EMBRY A., F. KLOVAN J., E. (1971) A late devonian reef tract on northeastern Banks Island, NWT. Bull. Can. Petroleum Geol. 19 : 730 – 781 .

[15]CATUNEANU O. GALLOWAY W., E. KENDALL C., G., S., C. MIALL A., D. POSMENTIER H., W. STRASSER A. TUCKER M., E. (2011) Sequence stratigraphy: methodology and nomenclature. Newsletters on stratigraphy, Vol. 44 **(3)** : 173–245.

[16]DUNHAM R., J. (1962) Classification of carbonates rocks according to depositional texture. American Ass. of Petroleum Geo. 43: 1-38.

[17]MOUNT J. (1985) Mixed siliciclastic and carbonate sediments: a proposed first-order textural and compositional clasification. Sedimentology, 32. p 435-442.

[18]WILSON J., L. (1975) Carbonate facies in geologic history. New York : Springer-Verlag. p. 971.

[19]FLUGEL E. (2010) Microfacies of carbonate rocks. Analysis, interpretation and application, 2nd edn. Berlin, Heidelberg. New York: Springer-Verlag. p. 976.

[20]TIPSWORD H., L. SETZER F., M. SMITH L., F. (1966) Interpretation of depositional environment in Gulf Coast petroleum exploration from paleoecology and related stratigraphy. Gulf Coast Association of Geological Societies, Vol. XVI : 119-129.

[21]JONES R., W. (1994) The challenger foraminifera. Oxford : Oxford University Press. p. 149.

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