JOURNAL OF APPLIED GEOSPATIAL INFORMATION

Vol 7 No 2 2023

http://jurnal.polibatam.ac.id/index.php/JAGI
ISSN Online: 2579-3608

Diagenesis Analysis of Padengo Limestone Area, Gorontalo Regency Based on Petrographic Method

Fikri Boften[1], Aang Panji Permana[2,*], Muhammmad Kasim[3]
[1,2,3] Geological Engineering Study Program, Universitas Negeri Gorontalo, Jl.Dr.Zainal Umar Sadiki, Bone Bolango, Indonesia.

[*]Coressponding author e-mail: aang@ung.ac.id

Received: January 16, 2023
Accepted: July 10, 2023
Published: July 10, 2023

Abstract

Carbonate rocks are rocks composed of carbonate minerals that are chemically formed in the form of solutions, and there are organisms involved in their formation. The limestone found around Lake Limboto is very interesting, because the water in the lake is freshwater while the limestone is characteristic of a marine environment. Diagenesis is a natural process in sedimentary rocks that occurs from the initial deposition until it reaches the limit of metamorphism will be formed. The research area is located in Padengo Village, West Limboto Subdistrict, Gorontalo Regency with a research area of 7.72 Km^2. This research aims to analyze the diagenesis of limestone in the Padengo area of Gorontalo Regency using the petrographic method. The methods used are field geological survey and petrographic analysis. The results showed that the geology of the Padengo area is composed of a wackestone limestone facies unit, a crystalline limestone facies unit, and an alluvial sediment unit. The diagenesis type of the study area consists of neomorphism, micritization, dissolution, cementation, and dolomitization. From the type of diagenesis, it can be determined that the limestone diagenesis environment of the study area starts from the marine phreatic zone, then the burial zone, and ends at the meteoric vadose zone.

Keywords: Diagenesis, Limestone, Padengo, Petrography

1. Introduction

Limestone or carbonate rock is a rock composed of carbonate minerals that are chemically formed in solution form, and there are organisms involved in its formation. Limestone is formed either through the deposition of mechanisms or carbonated chemical processes derived from marine animals that will form reefs through the process of diagenesis (Maryanto, 2017).

Limestone in Gorontalo alone covers about 14,073 ha in Limboto and surrounding areas (Kusdarto, 2006). The limestone around Lake Limboto is very interesting, as the water in the lake is freshwater while the limestone is characteristic of a marine environment (Permana *et al*., 2021a). The research area based on the geological map by Bachri *et al*, (1993) is included in the Clastic Limestone formation (TQl) which consists of carbonate rocks such as calcarenite, calcirudite, and coral limestone. Meanwhile, referring to the latest research conducted by Permana et al (2021b), the research area is part of the Late Miocene-Early Miocene Limboto Limestone Formation (TLL).

Diagenesis is a natural process in sedimentary rocks that occurs from its initial deposition until it reaches the limit of metamorphism will be formed (Ehlers, 1980). Micritization, dissolution, compaction, cementation, dolomitization, and recrystallization are diagenesis processes that occur in carbonate rocks controlled by complex factors, namely primary mineralogy, texture, porosity, and permeability, structure, and chemistry (Permana, 2019). The state of limestone, which is very easy to change with geological conditions, can certainly provide good information about geological history (Scholle, 1978; Kendall, 2005).

Studies on carbonate rocks are still lacking, even though in their development carbonate rocks or limestone have an important role in human life. For example, in the world petroleum industry, carbonate rocks as petroleum reservoirs, where 40% of petroleum in the world comes from carbonate rocks (Koesoemadinata, 1980). The existence of carbonate rock studies, especially regarding diagenesis or microfacies processes that can determine the deposition environment, is certainly very necessary. Based on the background that has been explained, the purpose of this research is to analyze the

diagenesis of limestone in the Padengo Area, Gorontalo Regency based on Petrographic Method.

2. Research Location

This research location is administratively located in Padengo Village, West Limboto Subdistrict, Gorontalo Regency, Gorontalo Province, and geographically located between 00º 40' 13.4" - 00º 38' 42,4" North latitude and 122º 53' 30.2" - 122º 54' 59.6" East longitude with an area of 7.72 Km^2 (Figure 1).

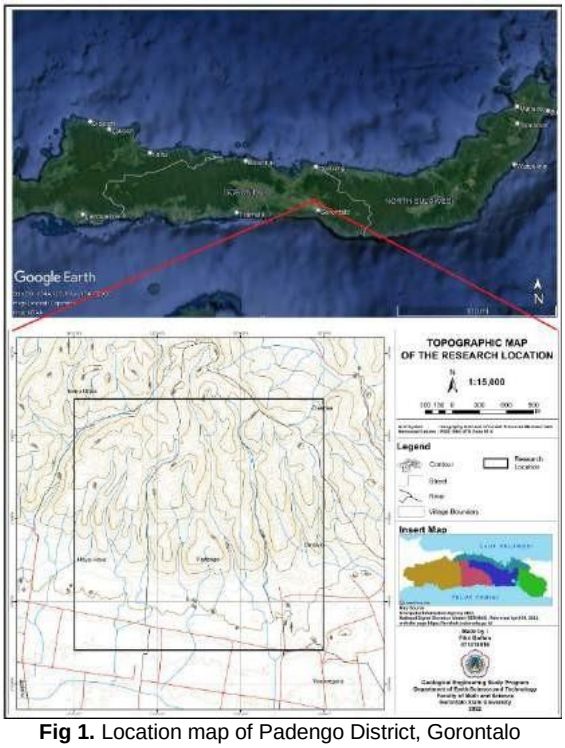

Fig 1. Location map of Padengo District, Gorontalo Regency

3. Research Methods

The research methods used are field geological survey, laboratory research, and studio processing. The field observation method is a method that focuses on observing the geological conditions in the research area. Then the data obtained were analyzed using laboratory research methods in the form of petrographic analysis with thin sections (Tetley and Daczko, 2013; Serge and Senthilkumar, 2017; Ofulume et al., 2018; Payuyu *et al*., 2022).

Petrographic analysis of the limestone under a microscope to determine the number and type of limestone particles used to name the rock. The classification of the limestone uses the classification according to Dunham (1962) and Embry and Klovan (1971). In addition, petrographic analysis was used to analyze the type of porosity of the limestone to determine the type of diagenesis. This type of diagenesis can determine the limestone diagenesis environment (Permana, 2019; Permana *et al*., 2022).

4. Results and Discussion

4.1 Stratigraphy

The arrangement of stratigraphic units in the study area refers to the classification of unofficial naming systems based on the similarity of lithological features found in the study area and also the results of the petrographic analysis in the laboratory. The stratigraphy in the study area is sorted from the oldest unit to the youngest unit, namely wackestone limestone facies, crystalline limestone facies, and alluvial units.

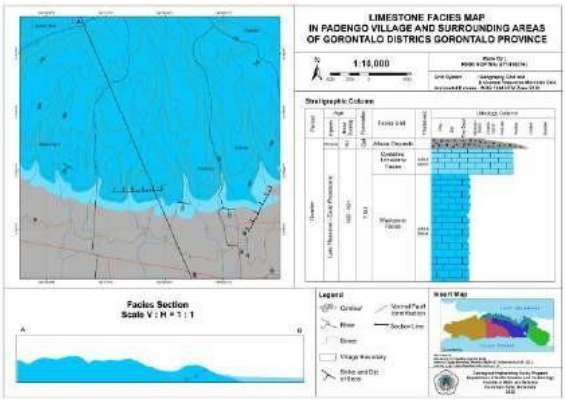

Fig 2. Limestone Facies Map of Padengo District, Gorontalo Regency

Wackstone Limestone Facies

These facies is the oldest unit in the study area. Megascopically, this facies is white-yellowish in color, with shell fragments embedded in the matrix, moderate sorting, good porosity, compact, and predominantly mud-supported texture (Figure 3).

Fig 3. Outcrop and hand specimen of wackestone limestone facies at outcrop FB-3.4

Microscopic observation of several samples (FB-1.4; FB-2.4; FB-3.2; and FB-3.4) taken from this unit shows pale yellow-brownish carbonate rock incision, with particle size <0.1 - 2.0 mm, mud-supported texture, open container with the abundance of porosity 5 - 15% consisting of vuggy, intraparticle, and interparticle porosity. Based on its composition, the rock is composed of skeletal grain in the form of foraminifera, algae, and coral fragments, non-skeletal grain in the form of extraclasts, peloids (FB-3.2), and non-carbonate grain in the form of volcanic lithics (FB-3.4), with a matrix of micrites. In addition, there is carbonate cement in the form of calcite with blocky and meniscus structures.

Crystalline Limestone Facies

These facies is the oldest unit in the study area. Megascopically, this facies is yellowish on the outside and white on the inside, carbonate in composition, compact, with a crystalline texture and has a layered structure (Figure 4).

Fig 4. Outcrop and hand specimen of crystalline limestone facies at outcrop FB-1.1

Microscopic observation, in this unit, is shown in sample FB-1.1 with a pale yellow appearance, with a particle size <0.1 - 0.2 mm, rock texture cannot be observed because it has undergone very intensive crystallization. There is porosity with an abundance of 10%, which consists of vuggy and intercrystalline porosity. Based on its composition, the rock is composed of carbonate cement dominated by calcite and minor dolomite.

Alluvial Deposition Unit

This unit consists of loose fragments that are clay to skeletal in size. These fragments consist of limestone fragments and there are also igneous rocks such as andesite. This unit is the result of weathering of surrounding rocks and transportation (Figure 5).

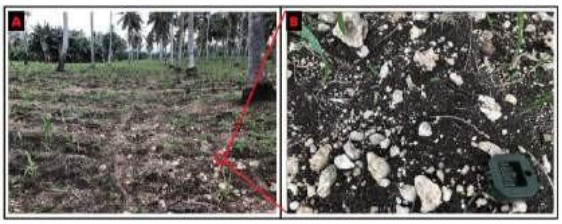

Fig 5. Alluvial sediment unit composed of loose clay to pebble-sized material

4.2 Diagenesis Type

The data from a petrographic analysis that has been conducted on 5 samples taken from the research site, namely FB-1.1, FB-1.4, FB-2.4, FB-3.2, and FB-3.4 show several records of the process or type of diagenesis that occurred in the limestone of the research area. The types of diagenesis include neomorphism,micritization, dissolution, cementation, and dolomitization (Figure 6 and Figure 7).

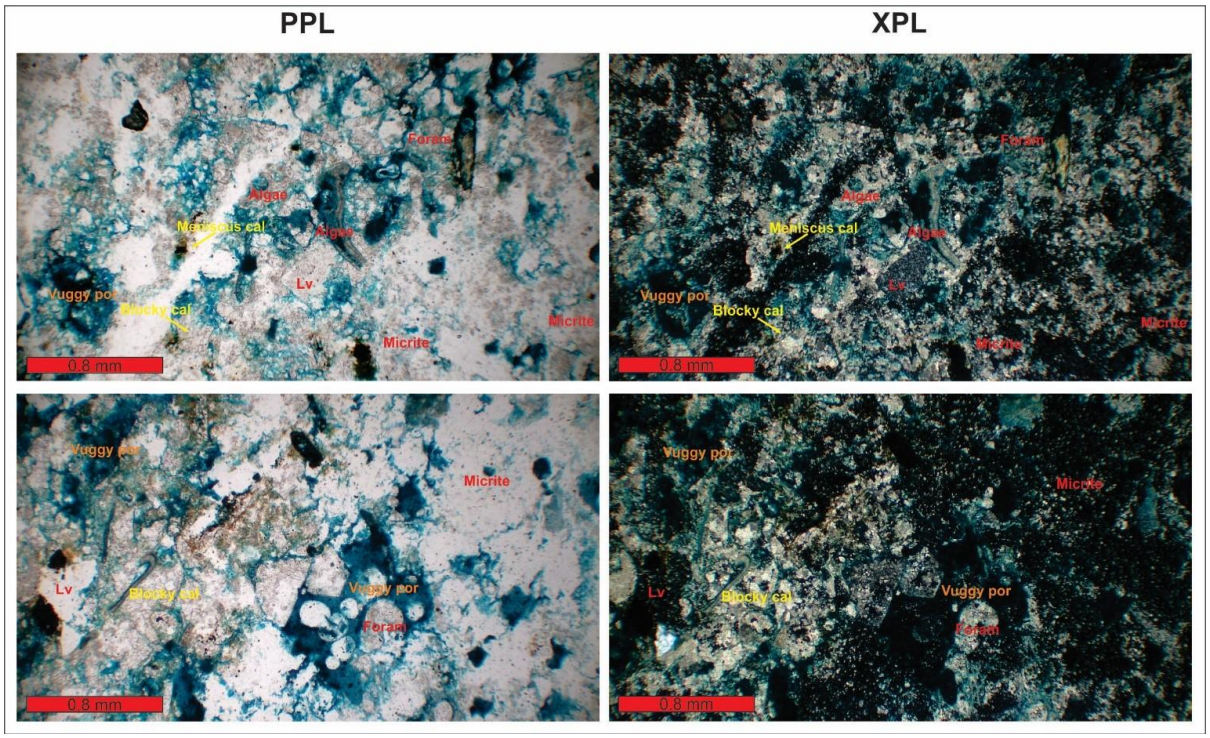

Fig 6. Petrographic analysis of the thin section of sample number FB-3.4

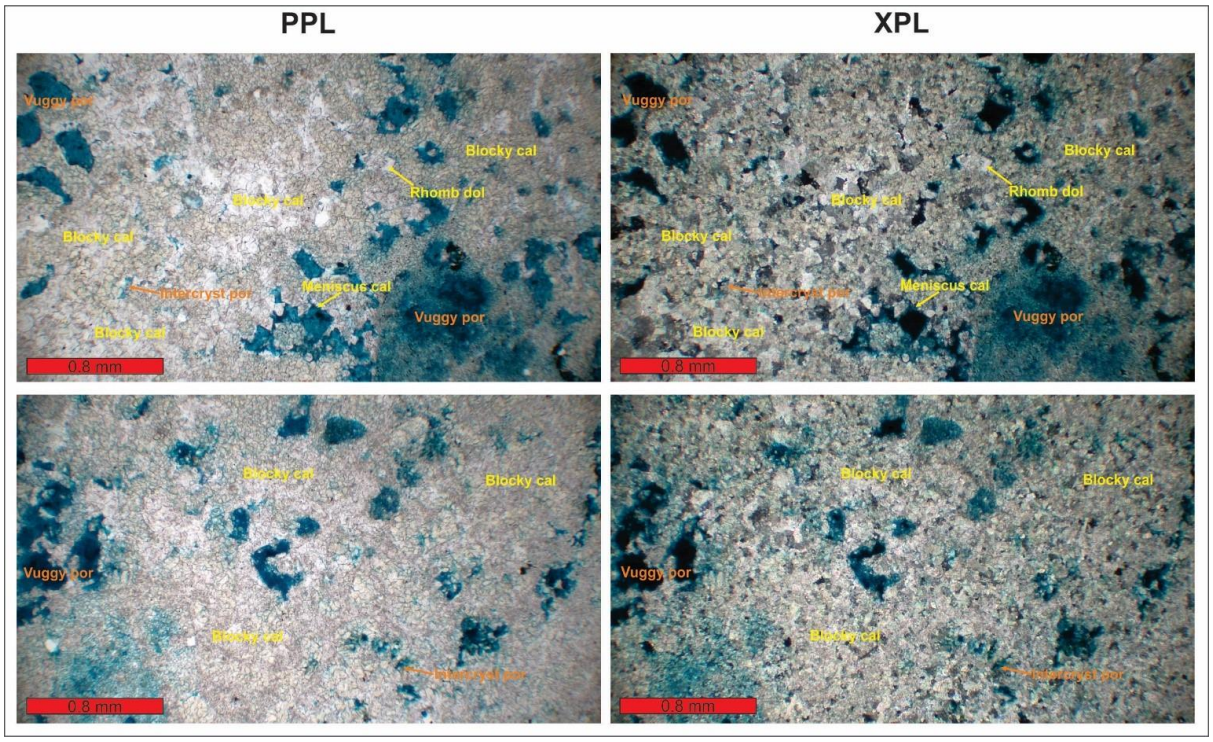

Fig 7. Petrographic analysis of the thin section of sample number FB-1.1

1. Neomorphisms

The observed neomorphism process is in the form of replacement or change in limestone composition. This process occurs in all rock samples, where there is an inversion in the form of changing the composition of shells or coral fragments into calcite and recrystallization in the form of changing micrite into blocky calcite.

2. Micritization

The process of micritization was only observed in some rock samples (FB-2.4 and FB-3.2) with a limited amount of micrite filling in the pores of the coral fragments and the formation of peloids. The micritic cement is unevenly distributed with a small amount.

3. Dissolution

The dissolution process that occurs in limestone can occur in various diagenetic environments. As occurred in the limestone in the study area which took place in a vadose meteoric environment. This dissolution process is observed in all samples with the presence of porosity cavities in the form of holes or vuggy. The size of the porosity cavities encountered can be micro to large and have been connected to each other to form a channel pore cavity.

4. Cementation

The cementation process can be observed in all rock samples. This process observed in the limestone of the study area is the production of calcite cement. This cement is present as a granular binder and fills dissolution voids and changes the composition of the shell or coral. Calcite cement is generally bladed - equent and dominated by meniscus and blocky structures.

5. Dolomitization

The dolomitization process was only observed in one rock sample (FB-1.1) which is a crystalline limestone. The dolomitization observed is the result of the replacement of micrite cement with dolomite locally in the rock sample. This dolomitization has a rhombohedral dolomite (CaMg(CaCo3)2) structure and fills the pore cavities and changes the composition of the shell or coral.

4.3 Diagenetic Environment

Based on the analysis of diagenetic processes or products through petrographic incision analysis, it is possible to interpret the diagenetic environment through which the limestones in the study area pass. Referring to the model of Tucker and Wright (1990), the study area consists of three diagenetic environments which include a marine phreatic zone, burial zone, and meteoric vadose zone (Figure 8).

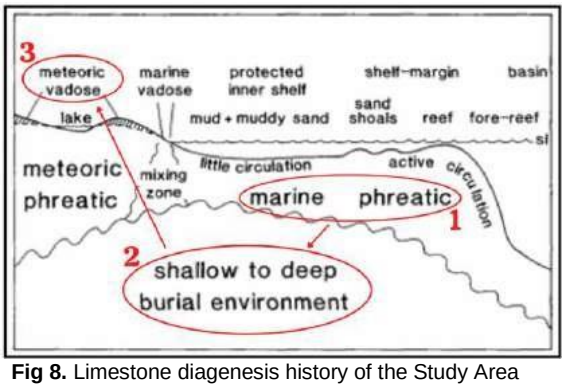

Fig 8. Limestone diagenesis history of the Study Area referring to the Tucker and Wright model (1990).

1. Marine Phreatic Zone

This zone is a place where the presence of sediment all pore space is filled with seawater. In this zone, the diagenesis process found the presence of micritization and cementation in several places. This is certainly following the diagenesis process described above, where in the observed rock samples there is a process of micritization and

cementation. In addition, this zone is characterized by the morphology of calcite cement which tends to be dominated by Blocky structures.

2. Burial Zone

The burial zone is where the pores of the rock are generally filled with seawater and the pressure rise that causes the compaction to work. This zone is characterized by the presence of calcite and dolomite cement. As found in sample FB-1.1, the dolomitization process is observed where the shape of the cement tends to be dominated by a bladed-equant shape, and the structure of calcite cement is dominated by a blocky structure and the presence of rhombohedral dolomite cement.

3. Meteoric Vadose Zone

The meteoric vadose zone is a zone located below the surface and above the groundwater table, causing cavities in rocks to be filled by meteoric water and air. In this zone, the diagenesis process that occurs is dissolution which produces vuggy porosity. This zone becomes the diagenesis environment of limestone in the research area, of course, based on the observation of the sample where there is a dissolution process and there is quite a lot of vuggy porosity filled by calcite cement with a meniscus structure.

From the analysis of the diagenetic environment identified through diagenetic processes or products, the stages of limestone diagenesis in the study area can be sequenced as follows, marine phreatic zone, burial zone, and meteoric vadose zone.

Starting from the marine phreatic environment which is generally the beginning of the diagenesis process in limestone characterized by the presence of micritization results in the form of micrite membranes that cover the shells of organisms. Furthermore, the loading and filling of the Limboto Limestone Formation (TLL) caused the diagenesis environment to change to burial. This environment is characterized by dolomitization and equent cementation.

At a later stage, tectonic activity resulted in rock uplift so that the diagenetic environment changed to meteoric vadose characterized by the presence of dissolution products that caused the formation of porosity with large vuggy cavities. This occurs because the rocks are in direct contact with meteoric water resulting in dissolution and the development of secondary porosity.

5. Conclusion

Based on the results and discussion of the study of limestone diagenesis analysis of Padengo Area, Gorontalo Regency using a petrographic method, it can be concluded that the research area is composed of wackestone limestone facies unit, crystalline limestone facies unit, and alluvial sediment unit. While the type or process of diagenesis found in the study area consists of neomorphism, micritization, dissolution, cementation, and dolomitization. From the type of diagenesis, it can be interpreted that the diagenesis environment of the research area starts from the marine phreatic zone, then the burial zone, and ends at the meteoric vadose zone.

Acknowledgments

Thank you to Nana, Ladya Cheryl Robot, and Rini Rahmatia S who have helped the author in collecting data in the field.

References

Bachri, S., Sukindo, dan N. Ratman. (1993). *Peta Geologi Lembar Tilamuta, Sulawesi Skala 1 : 250.000.* Pusat Penelitian dan Pengembangan Geologi, Bandung.

Dunham, R. J. (1962). *Classification of Carbonate Rocks According to Depositional Textures*.

Ehlers, E. G., Blatt, H. (1980). *Petrology*. W.H. Freeman Company. San Francisco

Embry, A. F., and Klovan, J. E. (1971). *A Late Devonian Reef Tract on Northeastern Banks Island, NWT*. Bull. Can. Petroleum Geol. Vol. 19. 730–781.

Kendall, C.G. (2005). *Lecture Slide: Stratigraphy and Sedimentary Basins*. The University of South Carolina, Department of Geological Science, Caroline.

Koesoemadinata, R.,P. (1980). *Geologi Minyak dan Gas Bumi.* ITB : Bandung.

Kusdarto. (2006). Prospek pemanfaatan lempung Danau Limboto sebagai bahan baku semen. *Buletin Sumber Daya Geologi. 1* (3): 30-34.

Maryanto, S. (2017). *Mikrofasies Batugamping : Studi Batugamping Paleogen-Neogen di Indonesia Bagian Barat.* LIPI Press, Jakarta.

Ofulume A.B. , Ib K.K., Ibeneme S.I., Dioha E.C., Chinemelu E.S., Eluwa J.C. & Onyeise U.O. (2018). The petrography, geochemistry and potential applications of Ndi-Uduma Ukwu/Ohafia-Ifigh limestone, Ohafia, S.E. Nigeria. *Journal of Geosciences and Geomatics, 6*(1), 21-26. DOI: 10.12691/jgg-6-1-3.

Payuyu, N., Permana., A.P., & Hutagalung, R. (2022). Analisis Tipe Batuan Dasar Pembentuk Nikel Laterit Pada Block X Kabupaten Banggai, Provinsi Sulawesi Tengah. *Jurnal Sains Informasi Geografi [J SIG],* 5(2),76-83. http://dx.doi.org/10.31314/j%20sig.v5i2.1551.

Permana, A. P. (2019). Tipe, Lingkungan dan Sejarah Diagenesis Batugamping Buliide Gorontalo Berdasarkan Analisis Petrografi. *Jurnal Geomine*, *7*(2), 79–86. https://doi.org/10.33536/jg.v7i2.327.

Permana, A.P., Kasim, M., dan Mamonto, F.K., (2021a). Analisis Lingkungan Purba Batugamping Daerah Limboto Barat Kabupaten Gorontalo. *Jurnal GEOSAPTA*, 7(2), 97-102. http://dx.doi.org/10.20527/jg.v7i2.10681.

Permana, A.P., Pramumijoyo, S., Akmaluddin and Barianto, D.H. (2021b). Planktonic foraminiferal biostratigraphy of the Limboto Limestone, Gorontalo Province, Indonesia.

Kuwait Journal of Science. Vol. 48. No. 1. 116-126. https://doi.org/10.48129/kjs.v48i1.6916

Permana, A.P., Eraku, S.S., Hutagalung, R., and Isa, D.R. (2022). Limestone Facies and Diagenesis Analysis in the Southern of Gorontalo Province, Indonesia. *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, 6* (456), 185-195. https://doi.org/10.32014/2022.2518-170X.248

Scholle, P. A. (1978). *A color illustrated guide to carbonate rock constituents, textures, cements, and porosities*. Tulsa: American Association of Petroleum Geology Memoir 27, 241.

Serge N., Senthilkumar G.R. (2017). Petrography of crystalline limestone and the associated rocks occurred near Uthappanaickanoor Village, Usilampatti Block, Madurai District, Tamil Nadu, India*. IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG),* 5, 54-62.

Tetley M., Daczko N.R. (2013). Virtual petrographic microscope: a multi-platform education and research software tool to analyse rock thin-sections. *Australian Journal of Earth Sciences, 61*(4), 631-637. DOI: 10.1080/08120099.2014.886624.

Tucker M.E., and Wright V.P. (1990). *Carbonate sedimentology.* Blackwell, Oxford, 482 p.