Effect of diagenetic events on limestone reservoir quality: Case study of Parigi formation, Northwest Java basin

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Abstract. Limestone is a sedimentary rock with high heterogeneity. This is triggered by diagenetic processes that affect the quality of limestone during its formation. The high uncertainty in limestone porosity values is also influenced by diagenetic processes. The Parigi Formation is a carbonate rock located in the Northwest Java Basin and has been proven to be a carbonate reservoir rock. Petrographic analysis was conducted to observe the appearance resulting from diagenetic processes. The studied area's limestone has two facies: clastic facies and reef facies. The limestone of clastic facies is white to greyish, consisting of skeletal fragments or shell fragments, with some places contains fragmented coral fragments. It is grain-supported, massive, poorly sorted, with fragment sizes ranging from 1mm-8mm and in some places 10cm-20cm. The reef facies of limestone are generally white to greyish colour, compact/massive, without cavities, and shows the body structure of coral/reef. The processes occurring in the Parigi Formation limestone, based on thin-section data, include cementation and neomorphism, which are commonly found in thin section LP 7 and LP 10. Cementation and neomorphism lead to a decrease in porosity in the limestone. Samples LP 1 - LP 5 show extensive dissolution, resulting in vuggy cavities/porosity. These limestone samples have high porosity values. The transformation of fossils into new crystals or recrystallization processes also reduces the limestone's porosity. Some samples also show that the cavities in the Parigi Formation limestone have been filled by calcite cements, thus closing the pores. This leads to poor quality limestone. In conclusion, the heterogeneous nature of limestone is significantly influenced by diagenetic processes. Petrographic analysis of the Parigi Formation limestone revealed the occurrence of cementation, neomorphism, dissolution, and recrystallization processes, all of which have implications for porosity and reservoir quality.

1 Introduction

The geological characteristics and diagenetic processes affecting reservoir quality in limestone formations have long been of interest in the field of petroleum geology. Limestone reservoirs are known to undergo significant modifications due to diagenesis [1], which encompasses a range of physical, chemical, and biological processes. Understanding the influence of diagenetic events on reservoir quality is essential for effective exploration and production of hydrocarbons in limestone reservoirs. This research was conducted on the carbonate rocks of the Parigi Formation in the Pangkalan Karawang area. The Parigi Formation consists of clastic limestone and reef limestone, which are oil and gas reservoir rocks found in the Northwest Java Basin [2], dating back to the Miocene period [3]. Diagenetic processes in carbonate rocks have influenced the formation of limestone [4]. The resulting formations from diagenesis are believed to be responsible for the degradation of reservoir quality [5]. This study focuses on the case of the Parigi Formation, which has been found to possess specific characteristics influenced by diagenesis.

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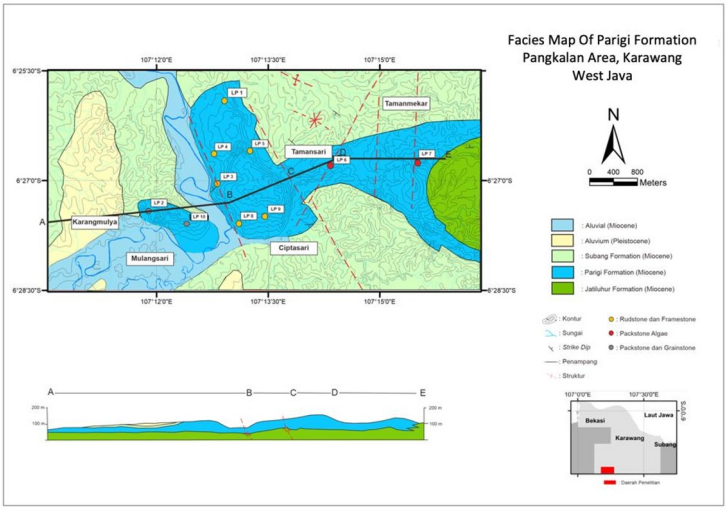

Fig. 1. Map of Research Location & it Facies (Modification of Achdan & Sudana,1992) [1]

2 Data and Method

The data was collected from field observation that has 10 different locations represent outcrop of Parigi Formation in Pangkalan, Karawang. Outcrop observation was conduct in this research (Fig.1). Megascopic rock descriptions were also conducted in the field. Rock sampling was carried out in different facies. 10 rock samples were collected and subsequently cut for petrographic thin section preparation. Petrographic analysis was conducted to visually examine the formations resulting from diagenetic. Visual porosity was observed under the polarize microscope to determinate genetic porosity that caused by diagenetic process. Quantitative facies analysis was performed to ascertain spatial distribution of carbonate rock facies. The dissolved cavities and mineral compositions were examined to understand the diagenetic processes and their impact on reservoir quality. The data obtained from field observations, petrographic, and porosity analysis were analysed and interpreted to gain insights into the depositional environment, diagenetic processes, and reservoir characteristics of the Parigi Formation with the Clastic & Reef facies.

3 Result and Discussions

The exposed Parigi Formation in the Pangkalan Karawang area is characterized by two facies variations, namely the clastic Packstone facies and the reef framestone facies. The Packstone facies is characterized by greyish-white colour, with skeletal fragments ranging from approximately 2-3 mm, grain-supported, and composed of Large Foraminifera, algae, and unidentified small particles. Additionally, this facies exhibits laminated layering structures. The second facies, the reef framestone facies, is characterized by a massive structure and intact coral fragments, as well as broken fragments of reef coral (Fig. 1). This facies only found in the central part of the research area.

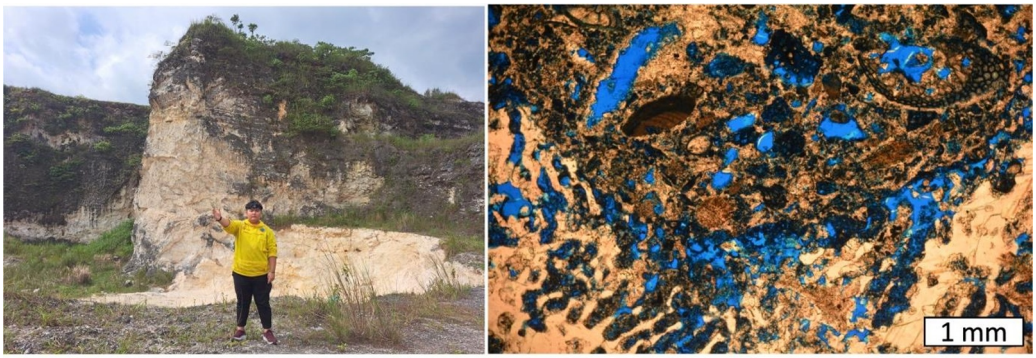

Fig. 2. Appearance of limestone with Framestone facies LP 1 (left) and thin section of Framestone limestone (right).

The above figure 2 shows the Framestone facies in the Parigi Formation exposed in the central part of the research area and its surroundings. It appears as greyish white in colour and is composed of densely packed reefs ranging in size from 1-10 cm. The structure of this facies appears highly massive. It is characterized by numerous broken coral fragments at the base, indicating a shallow marine environment where coral reefs thrived. In the petrographic thin section image (right photo), the appearance of dissolved coral reefs due to diagenetic processes is evident. The blue colour in the thin section photo reveals cavities formed as a result of dissolution during rock formation. Cementation in these facies also disrupted due to intense dissolution processes. The white colour in the thin section indicates the dissolution of the coral body. These cavities form two genetic porosities according to [2] vuggy porosity and moldic porosity. Both porosities are formed as a result of diagenetic processes, specifically dissolution. Dissolution has the potential to transform previously tight facies into one with more pores or porosity within the carbonate rock. This is due to the easily soluble nature of carbonate rocks and the instability of the Calcite carbonate mineral. Therefore, the diagenetic dissolution process enhances the reservoir quality, making it more favourable for hydrocarbon reserve. The Framestone facies is only distributed in the central part, which is believed to be the core of the reef where the reef body can be found. It is evident that a few meters away from the sampling site, similar facies with a more massive structure were discovered. Additionally, visible coral reef bodies ranging in size from 10-50 cm were observed, indicating no signs of dissolution in those outcrops. Therefore, it can be concluded that not all parts of the Framestone facies undergo diagenetic dissolution processes. The intense dissolution process indicates that this facies is associated with the Meteoric diagenetic environment.

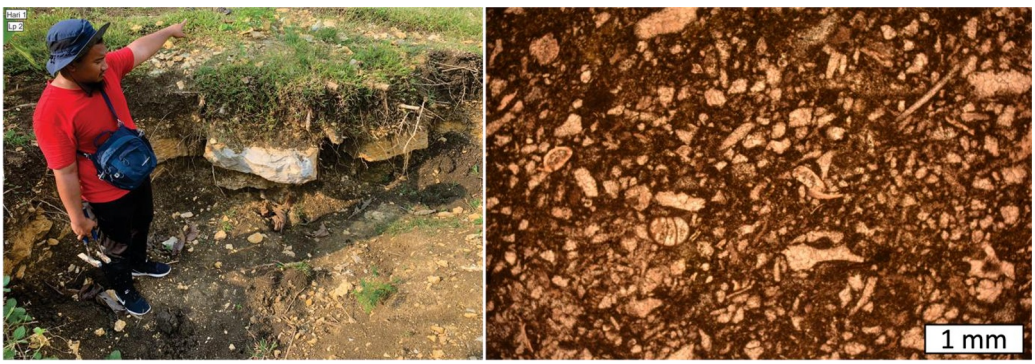

Fig. 3. Appearance of limestone with Clastic facies Packstone LP 2 (left) and thin section of Packstone limestone (right)

The above figure 3 shows a different limestone facies from the previous one, namely the clastic facies of limestone found in the Parigi Formation exposed in the Pangkalan Karawang area and its surroundings. This facies is characterized by a laminated structure, brownish-grey colour, and consists of skeletal fragments such as foraminifera shells and some lithic fragments. It is grain-supported with good to fair sortation, and the fragment size ranges from 1-5 mm. This facies can be found in the western and eastern parts of the research area. The figure 2 was taken in the eastern part of the research area. There are several molds or casts of trace fossils, indicating disturbances during the deposition of this facies. In the petrographic thin section photo of the Packstone facies

(right), it is evident that the rock is filled with numerous skeletal fragments, including several large foraminifera, lithic fragments, and some planktic foraminifera. All these fragments have been transformed into calcite crystals due to neomorphism processes during diagenesis. Similarly, the matrix that formed has been transformed into micrite due to neomorphism processes in a water-saturated environment. Furthermore, no visible pores or cavities are present in this facies, indicating that diagenetic dissolution processes did not occur. Therefore, this facies have poor potential for reservoir quality in carbonate rocks due to its too tight. Equant and blocky-shaped cement is also abundantly formed in this facies, indicating that it belongs to the diagenetic environment of Meteoric Freshwater Phreatic.

Fig. 4. Appearance of limestone with Clastic facies Packstone LP 7 (left) and thin section of Packstone limestone (right)

Figure 4 depicts an outcrop of limestone with Packstone facies, taken in the western part of the research area. This facies is characterized by a layered physical appearance, although the clarity of the outcrop is hindered by dense vegetation. The colour of this facies varies from greyish white to brownish-grey, and it contains skeletal fragments, including shells, algae, and other lithic fragments. The fragment size ranges from approximately 1-5 cm, and the facies is grain-supported with good to fair sortation. The petrographic thin section image (right) illustrates the dense nature of this rock, as seen from the transformed fragments into calcite (pink colour) and the dominance of equant and blocky-shaped cement. Consequently, the interlocking fragments formed in this facies negatively impact the reservoir quality potential of the carbonate rock. The thin section also lacks any visible blue-dye, indicating the absence of pores or cavities in the rock. The absence of dissolution processes suggests that this facies shares the same diagenetic environment as the Packstone facies found in the eastern part, namely the Meteoric Freshwater Phreatic environment.

Fig. 5. Appearance of limestone with Clastic facies Packstone LP 10 (left) and thin section of Packstone limestone (right

The above figure 5 shows the Packstone facies captured in the eastern part of the research area. It is characterized by thin-layered structures, greyish-white colour, and skeletal fragments ranging from 1 cm to 5 cm in size, with some fragments measuring 1 mm to 5 mm. Bioturbation or trace fossils were found in the upper layer of this facies. It is grain-supported with good to fair sortation, and the filling fragments consist of planktic foraminifera, some large foraminifera, and a few lithic fragments, as observed in the petrographic thin section. The layered structure suggests that this facies was deposited under conditions influenced by gravity-induced sedimentation and calm seawater. The petrographic thin section (right) indicates that this facies is predominantly composed of micrite, which has undergone neomorphism processes. Dissolution processes are not well observed in this facies. It can be noted that there is a lack of visible pores or cavities within this facies. Equant and blocky-shaped cement are also observed in this facies. This condition suggests that this facies is associated with the Meteoric Freshwater Phreatic environment, indicating a water-saturated condition. Fluids passing through this facies in such an environment can lead to the transformation of carbonate rocks through neomorphism or recrystallization processes. This has the potential to negatively impact the reservoir quality of carbonate rocks in this area. In the same facies, it is assumed that similar environmental characteristics are present. Therefore, it can be concluded that in the Packstone facies in this area, diagenetic processes that affect reservoir quality are not extensive. Consequently, the reservoir quality of the carbonate rock in this facies is poor.

4 Conclusion

This study of the Parigi Formation in the Pangkalan Karawang area has revealed two distinct facies variations: the clastic Packstone facies and the reef Framestone facies. The Framestone facies represents a reef core with massive structures, intact coral fragments, and several dissolution features. It is indicative of a shallow marine environment conducive to the growth of coral reefs. On the other hand, the Packstone facies displays laminated layering structures and is characterized by skeletal fragments, including foraminifera and lithic fragments. It exhibits signs of neomorphism and lacks significant dissolution features. Packstone facies is associated with the Meteoric Freshwater Phreatic diagenetic environment, marked by equant and blocky-shaped cement. Framestone facies is associated with the Meteoric Freshwater Vadose. The reservoir quality potential of the Packstone facies is limited due to its tight nature and the absence of significant dissolution or porosity development.

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