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Facies and Diagenetic Level of the Upper Cibulakan and Parigi Formation, in Randegan and Palimanan Area

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Abstract - This research aims to determine the facies and diagenetic level of limestone of the Upper Cibulakan and Parigi Formations, and also aims to determine the structural correlation between surface and subsurface limestones. Based on thin section analyses taken from the core and outcrop samples, there are four types of lithofacies on the Upper Cibulakan Formation, *i.e.* mudstone-wackestone, wackestone-packstone, packstone-grainstone, and grainstone facies, and also four types of lithofacies on the Parigi Limestone Formation, *i.e.* mudstone-wackestone, wackestone-packstone, packstone-grainstone, and lower mudstone-wackestone facies. The analysis of surface and subsurface limestone facies of the Upper Cibulakan and Parigi Formations led to the knowledge of the proportionality and variation of the limestone characteristics on both positions. Limestone of the Upper Cibulakan Formation was deposited locally and discontinuously, whilst the Parigi Formation limestone was deposited evenly and continuously. The structural correlation between the surface and subsurface limestone indicates that these formations were uplifted/exposed due to a local force, likely caused by the intrusion of igneous rocks, as happened in the Kromong Complex. The presence of residual hydrocarbon on the surface of the limestone samples suggests the possibility of potential hydrocarbon trapped in the limestone beneath the surface.

Keywords: carbonates, Parigi Formation, Upper Cibulakan Formation, facies, diagenetic, Kromong Limestone

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Introduction

Background

It has been known that almost 60% of world reservoir is carbonates rock (Schlumberger, 2014). Hydrocarbon production from carbonate reservoirs has been greatly expanded, such as Baturaja Formation in south Sumatra, Kais Formation in west Papua, Parigi Formation in northwest Java, and Kujung Formation in northeastern part of Java.

The unique features of carbonate rock, especially those occuring as reservoirs are the diversity of their physical properties, as well as the processes that occur to affect the characteristics, like their structure, chemical composition, and rock properties (Tucker and Wright, 1990). The diversity of carbonates/limestone, as well as the processes, do not always produce a favourable reservoir condition. Some processes even diminish and damage the quality of reservoir. A good understanding about carbonate facies and diage-

netic process is the key to a good determination of carbonate reservoirs (Walker and Noel, 1992).

The Parigi and Upper Cibulakan Formations are two of several formations in the Northwest Java Basin that produce hydrocarbon, and they still have the potential as reservoirs. These formations are well exposed in the study area which located at the Kromong ridges in Palimanan, Cirebon Area (Figure 1). Praptisih *et al.* (2012) and Pringgoprawiro *et al.* (1977) determined the limestone facies analysis based on the data from limestone outcrop of Kromong Complex. In this study, observation and determination of limestone facies and diagenesis were conducted based on the data of seven wells, consisting of three geotechnical wells (on limestone outcrop) in Kromong Limestone, and four exploration wells in the northern part of the Kromong Complex.

METHOD

This study started with literature reviews from various sources and authors. Afterwards, it was

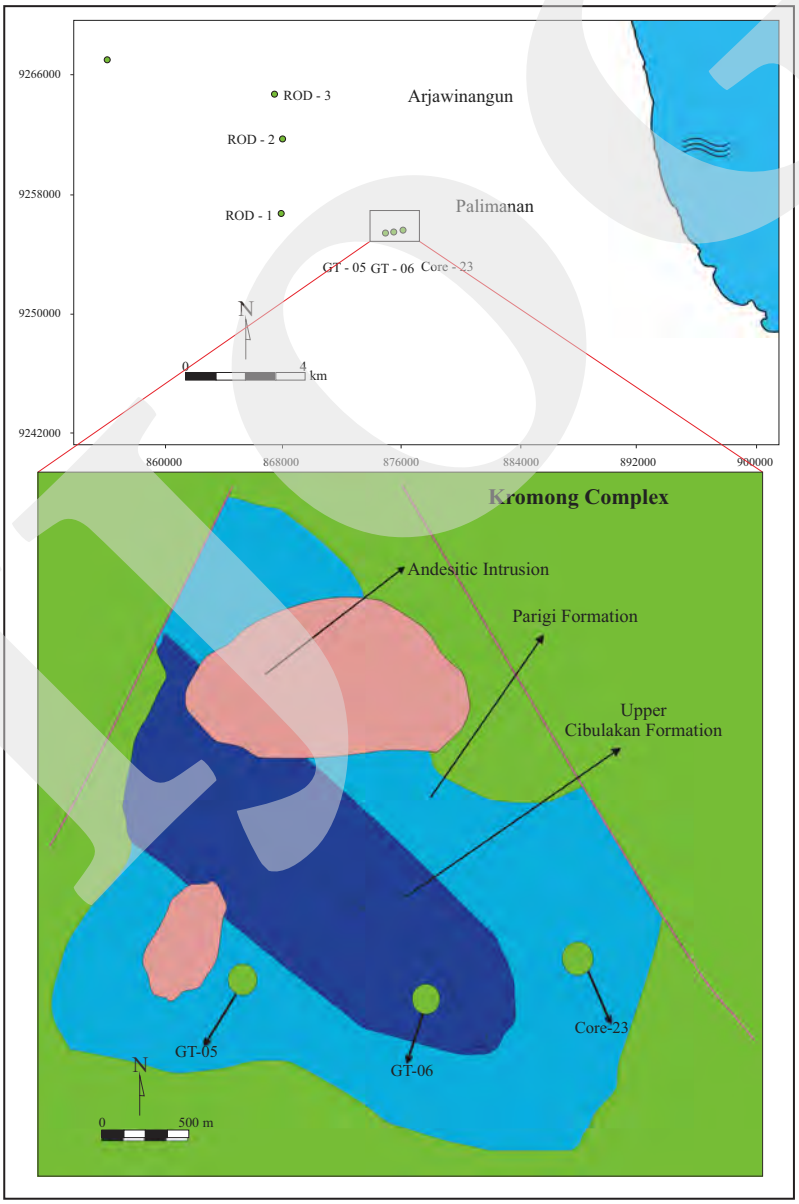

Figure 1. Locality map of the study area and well sites (upper) and the geological map of the limestone outcrop in the Kromong Complex (lower).

followed by visiting and observing the outcrop sites. In this stage, outcrop and core sample analyses were carried out from the three geotechnical wells (GT-05, GT-06, and CORE-23 wells). The samples were later prepared for petrographic, paleontologic, and calcimetric analyses. Figure 2 shows the lithofacies of CORE-23 well used in the observation.

Afterwards, the result of the observation was combined with the subsurface data. The data used

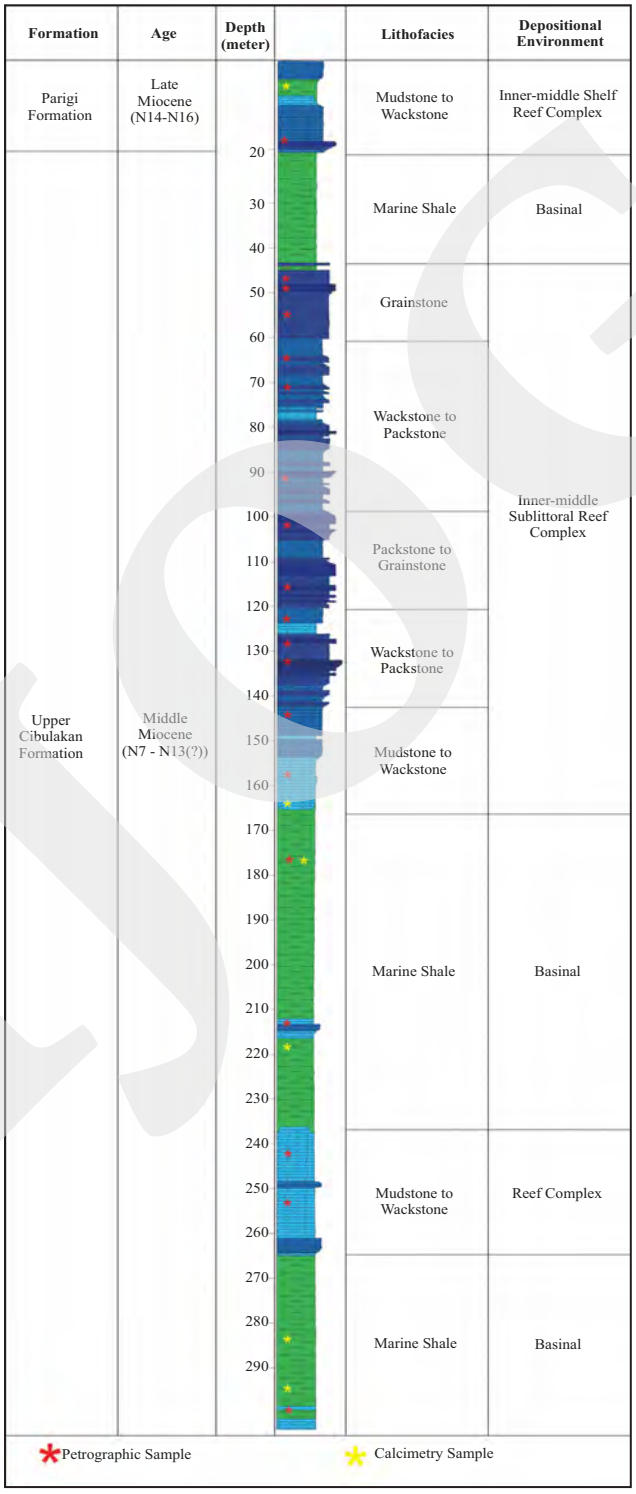

Figure 2. Well section of CORE-23 showing the determination of lithofacies and depositional environment.

are well log data from four exploration wells (ROD-1, ROD-2, ROD-3, and ROD-4 wells). The observation concerning facies and diagenetic was conducted on both surface and subsurface wells, and the conclusion was drawn regarding the facies correlation, diagenetic event, and also the structural correlation shown on the maps.

General Geology

The Northwest Java Basin is a Tertiary sedimentary basin located in the northern part of West Java, both onshore and offshore. This basin is bordered by Seribu Islands in the western part, Ardjawinangun (Kromong) High and Karimunjawa Platform in the eastern part, Sunda Shelf in the northern part, and Bogor Trough in the southern part. The formation of the basin is an impact of a geological structure which is north-south trending normal block faults. The development of this Tertiary Basin was considerably influenced by the Pre-Tertiary basement configuration and structure. Based on the study of Patmosukismo and Arpandi (1975), in ascending order, the lithologic units of the basin comprises:

1. Basement which consisting of low grade metamorphic and igneous rocks.
2. Jatibarang Formation comprising synrift deposits, that includes unfossiliferous volcaniclastic rock.
3. Talang Akar Formation overlying unconformably the Jatibarang Formation, comprises paralic deposits deepening upwards (to neritic bathymetry).
4. Baturaja Formation overlies conformably the rock beneath, consisting of built up limestone and platform, and becomes fine-grained sediments upwards.
5. Upper Cibulakan Formation which can be divided into three members, *i.e.* Massive Unit, Main Unit with the intercalation of limestone (Mid Main Carbonate), and pre-Parigi Unit.
6. Parigi Formation composed of porous and built up fossiliferous organic and platform limestone.
7. Cisubuh Formation overlying conformably the rock beneath and is dominated by claystone. The age of the sedimentation ranges approximately from Eocene to Pleistocene.

Nowadays, the basin is considered as a back-arc basin with a very complex configuration. It comprises a north-south trending half-graben, and other massive structures triggerring the basin formation, like migration path and hydrocarbon trap. Stratigraphically, the rock formations in the Northwest Java Basin support the petroleum system in the basin.

Result and Analysis

The observations can be considered into two work sections, those are the exposed limestone lithofacies analysis of which is based on the analysis of core samples and rock petrography taken from three geotechnical (outcrop) wells, and the unexposed limestone lihtofacies analysis of which is based on the analysis of well log (gamma ray log, sp log, resistivity log, density log, and neutron log) from four exploration wells and drilling reports.

Upper Cibulakan Formation

The observation results of the surface and subsurface wells show that the limestone distribution in Upper Cibulakan Formation is not continuously, but more locally, intercalating with thick marine shale. This formation is divided into four types of lithofacies *i.e.*:

Mudstone-Wackestone Facies

The distribution of this facies can be observed in the surface and subsurface wells. In the surface, it can be traced at GT-06 and CORE-23 wells, while subsurficially at ROD-2 and ROD-3 wells. This facies is characterized by greyish, fine-grained limestone. In some parts of the rock samples, especially GT-06 well, they appears to be some fractures which are also filled by hydrocarbon residue. Based on the appearance on thin sections, the limestone comprises micrite, small skeletal grains, and also rarely large foraminifera

fragments. The limestone is highly tight, almost no large porosity appears, and only present as a small-sized porosity (micro-interparticle, micro-fracture). However, based on the calculation using the density and neutron log, it is known to range between 10 - 13%, and estimated to be diminished downward. The diagenetic environment in this facies is expected as a marine phreatic regime. But in some parts, there are some evidences of a burial regime (Figure 3a, 3b).

Wackestone-Packstone Facies

The distribution of this facies can be observed at both surface and subsurface wells, except at ROD-1 and ROD-3 wells. The distribution is not extensive and continuous, yet local in certain places. This facies is characterized by grey coloured limestone. In some parts, it is white coloured, fine-grained, showing a lot of bioturbation as well as lamination. There are also many fractures and pores filled by hydrocarbon residue.

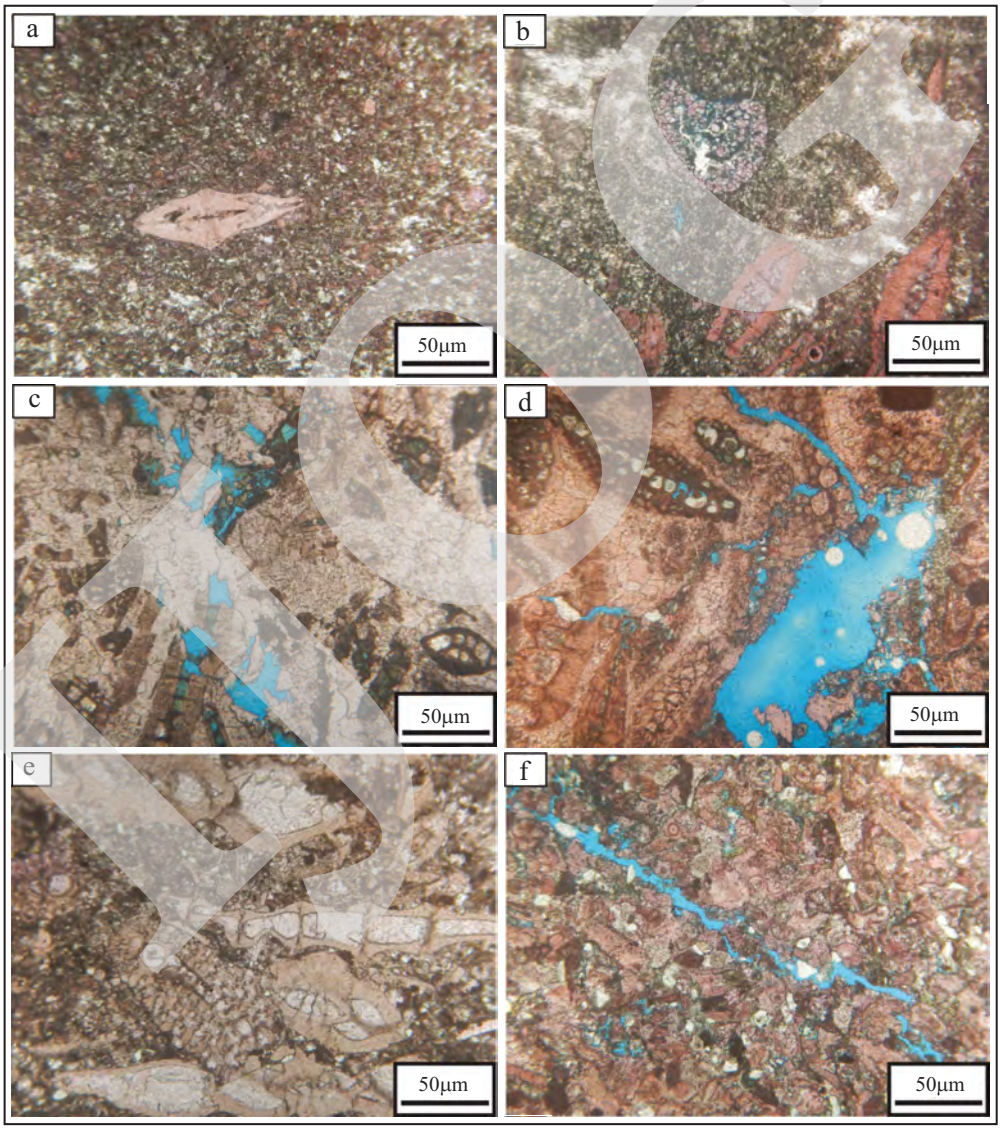

Figure 3. Photomicrographs of limestone samples of the Upper Cibulakan Formation. (a) tight mudstone facies limestone dominated by micrite, type of the cement is suspected as blocky, might be the evidence of fresh water phreatic regime – vadose regime; (b) mudstone - wackestone, dominated by micrite, there are also the appearances of pseudospar dolomite, and intraparticle porosity inside believed to be fossils (aragonite particle); (c) wackestone facies, with an appearance of vuggy porosity; (d) wackestone - packstone facies, with the appearances of huge vuggy porosity and possibly channel porosity, also dominated by blocky cement; (e) packstone-grainstone indicating a burial regime; (f) grainstone facies, with the appearance of a fracture porosity.

A number of porosity types, such as fracture, moldic, and vuggy, as well as equant/blocky cement type are recognized microscopically under transmitted white light mode on thin section samples. Based on the calculation using density and neutron log value, the porosity is estimated to vary between 10 - 17%. The diagenetic environment in this facies are suggested to be a marine - fresh water phreatic regime (Figures 3c and d).

Packstone-Grainstone Facies

This facies distribution which can be observed in the surface wells (CORE-23, GT-05, and GT-06 wells), is characterized by grey coloured limestone, medium-grained, some are fine-grained. Mostly are dominated by the equant type cement, some parts also appear to have abundant micrites. The type of porosities developing are vuggy, fracture, and moldic. In several samples, a number of fractures and pores are filled by hydrocarbon residue. The quantity of the porosity visually analyzed resulted in a value ranging between 0 - 10%. Despite the appearance of the vuggy porosity, it is believed that the blocky cement type and the intraparticle/moldic porosity type might be a special indication of a marine - fresh water phreatic regime (Figure 3e).

Grainstone Facies

In the Upper Cibulakan Formation, distribution of the facies can only be traced in GT-06 and CORE-23 wells. This facies is characterized by grey coloured, medium- to fine-grained limestone. In some parts, the core samples comprise packstone lithofacies. The porosity types that appear are fracture and moldic/intraparticle. There are also pseudospar dolomite recognized within thin section analysis, and the evidences indicate the limestone had experienced a burial regime, such as interlocking contact/sutures. The quantity of the porosity based on the visual analysis range between 0 - 10%. The diagenetic event is recognized as a marine - fresh water phreatic condition (Figure 3f).

Parigi Formation

The result of analysis shows that the Parigi Formation was deposited continuously and distributed almost evenly to all the wells, except GT-06 well. Such distribution model might be the evidence of Hall and Benyamin's (2007) research about the wide spread carbonate deposition in the Northwest Java Basin at the Late Miocene age. Based on the research, the Parigi Formation can be divided into four major lithofacies, these are:

Mudstone-Wackestone Facies

Distribution of the Parigi Formation can be traced on CORE-23 well, and spreads over the top of ROD-1, ROD-2, ROD-3, and ROD-4 wells. In the CORE-23 well, this facies is characterized by grey-coloured limestone, medium- to fine-grained size, which is coarser at the bottom. The occurrence of moldic and intraparticle type porosity which is adequately abundant can be the proof of a marine - phreatic diagenetic environment in this zone. Moreover, the occurrence of the fracture type porosity can be considered as the result of a tectonic process, cracking the limestone. Based on the analyses of density and neutron logs, the value of the porosity in this lithofacies ranges between 5 - 25% (Figure 4a).

Wackestone-Packstone Facies

This facies distribution can only be recognized in the four exploration wells. Density and neutron log analyses show that the thickness of this facies reaches more than 170 m, with the porosity ranging between 15 - 28%. Such a good value is believed to be influenced by a diagenetic environment that forms porosities, *e.g.* vadose - fresh water phreatic, and also the tectonics process (Figure 4b).

Packstone-Grainstone Facies

This facies distribution can only be seen in GT-05 well. This facies is characterized by white to grey-coloured, medium- to fine-grained limestone. In addition, it looks similar to platy coral and bioturbation. In this facies, the limestone intercalates within the claystone, and in some parts it becomes interbedded. Based on the appearance of the thin section, the limestone

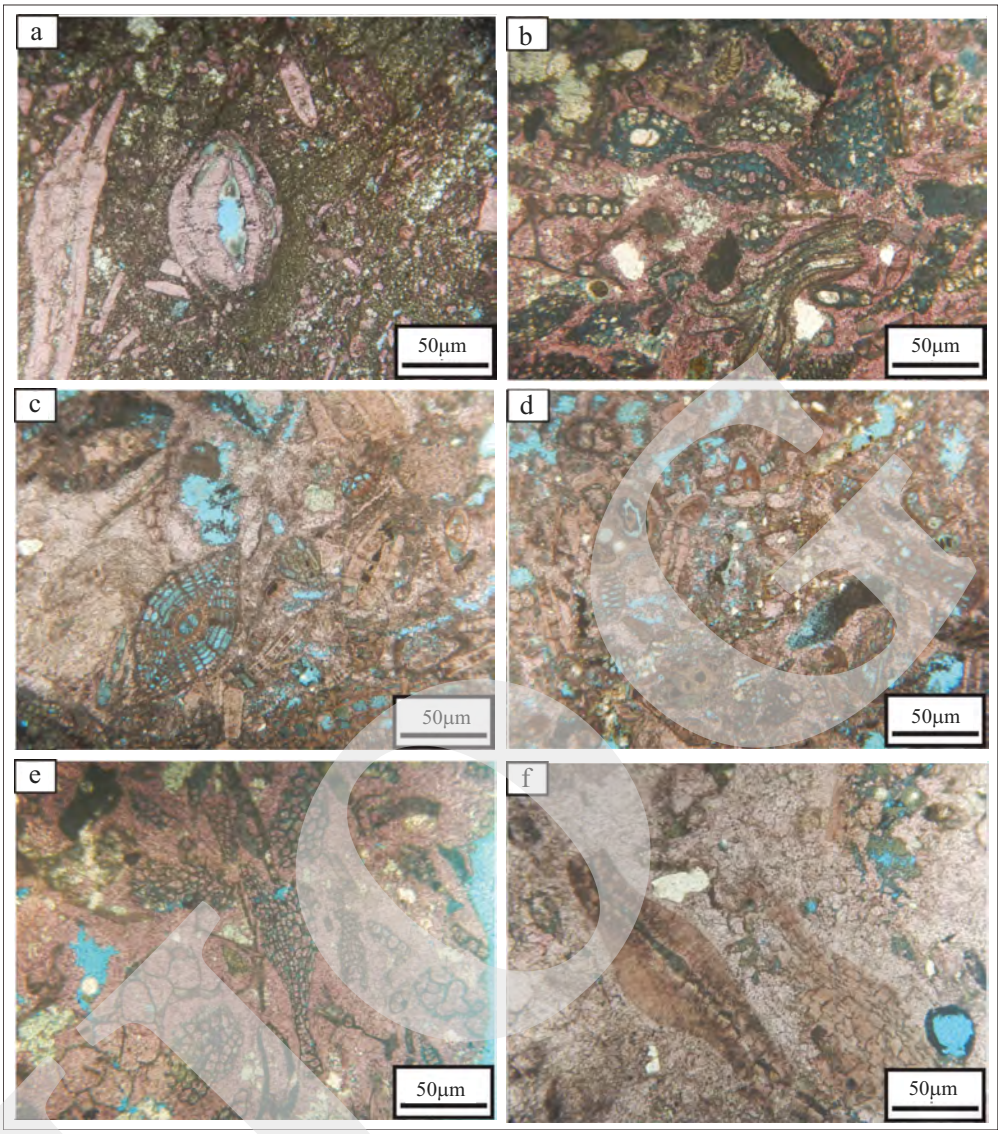

Figure 4. Photomicrographs of limestone samples of the Parigi Formation. (a) Mudstone-wackestone facies with intraparticle porosity. There are actually small interparticle porosities as well. The sample is dominated by micrite; (b) Foraminiferal packstone facies showing the abundance of mouldic type porosity. It also shows that the recrystallization process acts on the matrix; (c) Packstone-grainstone facies comprising intraparticle and vuggy porosities; (d) Grain (possibly to boundstone) limestone facies showing many types of porosity, such as interparticle, vuggy, shelter etc. In some part the porosity showing a dark / black stain besides the blue stain indicate the evidence of oil residue; (e) Wackestone facies composed of intraparticle and vuggy porosities. There is also the appearance of recrystalization process; (f) Wackestone facies. The micrite (matrix) has been recrystalized, and it is now dominated by blocky cement type.

contains a large number of foraminifera, both macro- and microforams (Figure 4c). Based on the thin section observation, the dominant visible porosity is known as vuggy and moldic type, considered to represent a fresh water phreatic environment. Moreover, there is also an impact of tectonic processes which generate the fracture porosity in this facies. The porosity ranges between 10 - 25% (Figures 3e and 4d).

Mudstone-Wackestone Facies

This facies shows a similar appearance with the mudstone-wackestone facies before, but the distribution is at the bottom of the Parigi Formation, and it can be traced at the subsurface wells, except ROD-4 well. The quantity of its porosity ranges between 5 - 20%, which was allegedly triggered by a diagenetic regime that generates porosity (Figures 4e and 4f).

Discussion

Based on the results of surface to subsurface limestone lithofacies analyses, it is known that the limestone distribution of the Upper Cibulakan Formation is discontinuous, but locally, mounded, isolated, and intercalated with marine shales. The Upper Cibulakan Formation is divided into four types of lithofacies, but in the whole body, it is dominated by mudstone-wackestone and wackestone-packstone facies. While the other types of facies, the packstone-grainstone and the grainstone facies, can only be traced and observed in the subsurface wells (CORE-23, GT-05, GT-06 wells). Unlike the Upper Cibulakan Formation, in Parigi Formation the limestone was deposited continuously from ROD-4 to CORE-23 wells. Based on this appearance, it is estimated that the limestone grows as a carbonate platform with an isolated reef. Moreover, the Parigi Formation is also divided into four types of lithofacies. Based on the type of porosity such as vuggy and moldic, also the appearance of micrite, recrystalization, blocky cement, etc., it is estimated that the Parigi Formation is in the zone of fresh water phreatic - vadose diagenetic regime. This is possibly because of the location of the formation which is close to the surface.

The diagenetic event occurring on those types of lithofacies is dominated by the marine phreatic - fresh water phreatic regime, as evidenced through the appearances of micritization, recrystalization process, and pseudospar dolomite. The thin section analysis also exhibits a considered number of fracture porosity, especially at the Upper Cibulakan Formation indicating a major tectonic process evidenced by the presence of cracking in the limestone. Some of the porosities are filled by what to be suspected as hydrocarbon residues (Figure 5). This may indicate the lost

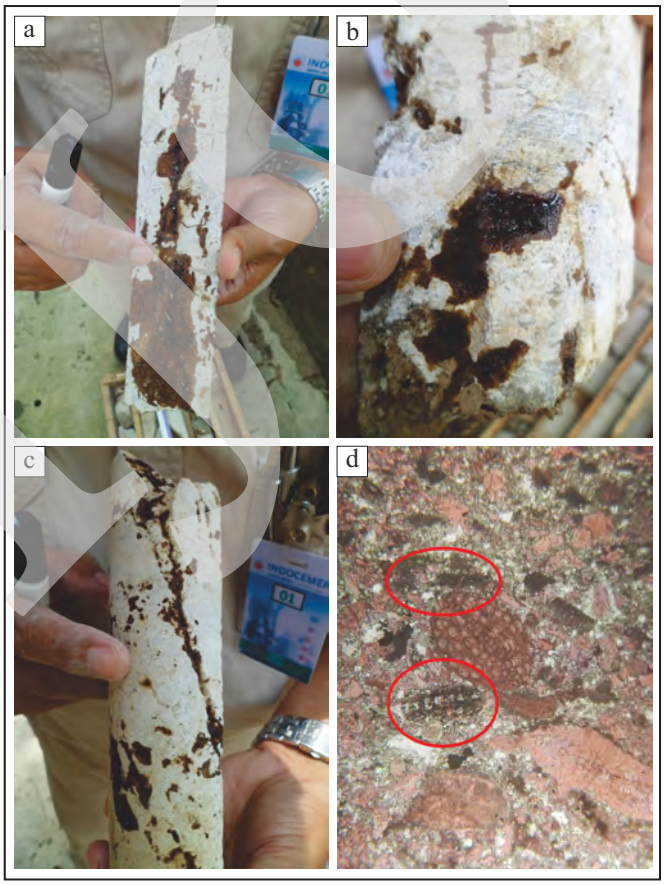

Figure 5. Photographs of the core samples from CORE-23 and GT-06 well (a, b, c) showing what to be expected as HC residue and photomicrograph of thin section (d) of the Upper Cibulakan Formation. The red circle mark the part of what should be a porosity (prob. Moldic type), that were filled by what to be expected as HC residue.

of hydrocarbon during the uplifting process, and also suggest the probability of hydrocarbon reserve at the northern subsurface limestone of the Upper Cibulakan Formation.

The analysis of structural correlation of all seven wells was carried out by leveling all the wells at 0 m. On the basis of the configuration of the surface - subsurface sections, and their coherence with the geological setting in Palimanan Area, it is known that the limestones of the Parigi and Upper Cibulakan Formations cropping out in the Kromong Complex, may be the result of a local uplifting process. The andesitic intrusion (Pringgoprawiro *et al.*, 1977) and the nearby reverse faults are expected to be the cause of the uplift (Figure 6). The configuration of both formations also shows an anticline in the exposed and unexposed parts. Despite the magmatic intrusion, the fold structure is expected to be the result of a bigger tectonic force.

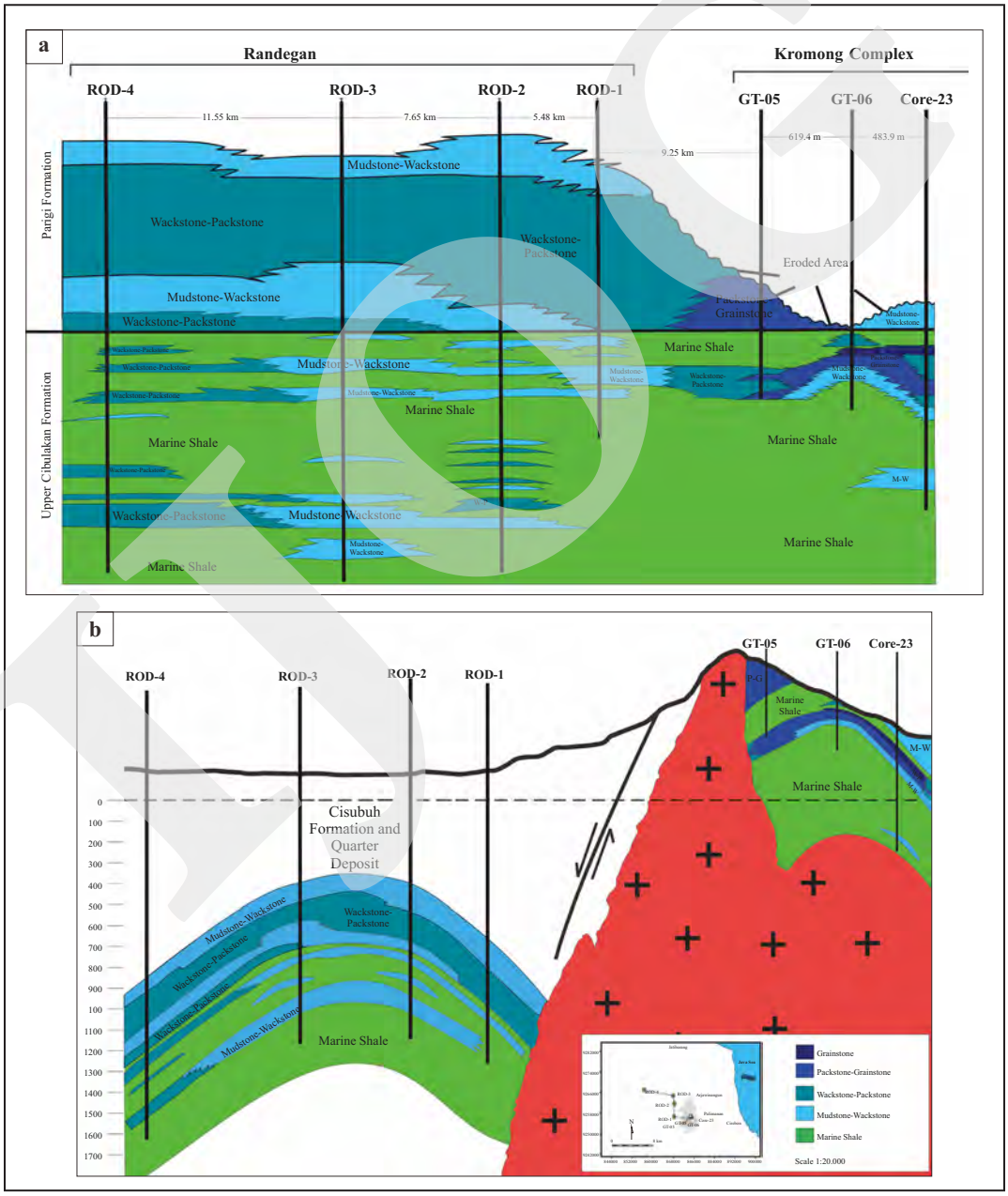

Figure 6. (a) Upper Cibulakan Formation and Parigi Formation lithofacies correlation of all seven wells; (b) Structural correlation shows the relationship between both formation from surface to subsurface.

Conclusion

1. The Upper Cibulakan Formation is divided into four lithofacies, *i.e*. mudstone-wackestone, wackestone-packstone, packstone-grainstone, and grainstone facies. The Parigi Formation is also composed of four lithofacies, *i.e*. mudstone-wackestone, wackestone-packstone, packstone-grainstone, and lower mudstone-wackestone facies.
2. The Upper Cibulakan Formation is presumed to be limestone mounds because of the unit occur locally and discontinuously; while the Parigi Formation is suggested to be a platform with parts of isolated reef, as it was deposited continuously.
3. The Upper Cibulakan Formation is dominated by a freshwater phreatic - marine phreatic regime, with the quantity of porosity ranging approximately between 10 - 15%, while in the Parigi Formation, the diagenetic events which occur are dominantly vadose - freshwater phreatic regime, with the quantity of porosity varies approximately between 10 - 20%.
4. Structurally, the connection between the surface and subsurface limestones is separated by a process of local uplift which caused some of both formations to be exposed at the Kromong Limestone Complex. It is expected to be due to the local magmatic intrusion and reverse fault.

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References

Hall, R. and Benyamin, C., 2007. Cretaceous to Late Miocene Stratigraphic and Tectonic Evolution of West Java. *Proceedings of 31st Annual Convention and Exibition of Indonesian Petroleum Association.*

Patmosukismo, S. and Arpandi, 1975. The Cibulakan Formation As One of the Prospective Stratigraphic Unit in the North-West Java Basinal Area. *Proceedings of 4th Annual Convention of Indonesian Petroleum Association*, p.181-210.

Praptisih, Siregar, S., Kamtono, Hendrizan, M., and Putra, P.S., 2012. Fasies dan Lingkungan Pengendapan Batuan Karbonat Formasi Parigi di daerah Palimanan, Cirebon. *Jurnal Riset Geologi dan Pertambangan*, 22 (1), p. 33-43.

Pringgoprawiro. H., Suwito, S., and Roskamil, P., 1977. The Kromong carbonate rocks and their relationship with the Cibulakan and Parigi Formation. *Proceedings of 6th Annual Convention of Indonesian Petroleum Association*, 1, p.221- 240.

Schlumberger, 2014. *Carbonate Reservoir, Technical Challenge.* web. June 30. (http://www.slb.com/industry-challenge/carbonate/)

Tucker, E.M. and Wright, V.P., 1990. *Carbonate Sedimentology.* Oxford, UK: Blackwell Publishing Co.

Walker, R.G. and Noel P. 1992. F*acies Model Response to Sea Level Change*. Canada: Geological Association of Canada, 409pp.