Grouping porosity permeability in deep marine sediment to analogue oil and gas reservoir: A case study Brebes Central Java

F Herdiansyah*, M Burhannudinnur, D Syavitri and O Ovinda
Departemen of Geological Engineering, Faculty of Earth and Energy, Universitas Trisakti Jakarta, Jakarta, Indonesia

*firman.herdiansyah@trisakti.ac.id

Abstract. Study area is located in Rambatan river and Ciseureh river Malahayu Brebes Central Java. Porosity and permeability are very important to oil and gas industry. Porosity is a measure of the void spaces in a rock and is a part of the total volume rock. Permeability is defined as the ability of a rock to transmit fluids. Deep-water gravity flow or deep marine reservoir are important exploration targets worldwide and there is complicated when little subsurface data available. Porosity and permeability analysis from outcrops data may considered as the data used in this study. The result from four measuring section show there is thin intercalated limy sandstone, marl, and calcareous shale. 14 outcrop samples was carried out the helium porosimetry for porosity permeability value and was examined thin section analysis for fabric discussion, and 2 samples was calcimetry analysis. Lithology are generally contains many foraminifera from very fine to fine grained and mostly moderate grained on inner-outer fan environment. Sedimentary structure represent slope sedimentary structure such as graded bedding, lower lamination, slump bedding, ripple, convolute ripple, cross lamination, and trace fossil as feature of deep-marine deposits. 8 samples from 14 samples limy sandstone are likely to be good reservoirs.

1. Introduction
Besides being a good source rock, deep marine sediments can also as good reservoirs both in Indonesia and worldwide. Understanding the physical and chemical properties of the rock are fundamental concept to know further whether rocks can be a good reservoir or nor. The studied area was the site of accumulation of submarine fan dominantly that underlie shelf deposits, with tectonic event responsible for the shallowing upward trend. They characteristics and configurations has been discussed in most published although that does not mean they are ignored, but would be further discuss about the physical characterization specifically both quality and quantify porosity permeability in deep marine deposits. The petroleum potential of Central Java is indeed still quite difficult to understood. Petroleum exploration activities in Central Java were started in the late 1800s following the discovery of oil seepages [1]. Outcrop-based samples can make it easier for geologists to understand the history of sedimentation and the role of different diagenetic modifications in reservoir properties, and to be analogous to predictions of subsurface porosity and permeability.

Deep-marine sediment reservoirs have heterogeneous lithology and complex architectures. Deep marine sandstone reservoirs are complicated and subsurface data that are expensive and difficult to
obtain, then only uses seismic and log data to interpret. The objective of this study is to provide insight of sedimentology and related to deep marine reservoirs properties characterization as a reference to oil and gas exploration. sedimentology parameters that can be observed are texture, sedimentary structure, depositional environment can also be key parameters to divide porosity and permeability group.

Central java was be elected as the research area because it has a unique geological phenomenon compared to both West Java and East Java. One of the uniqueness of Central Java is that the coastline of Java Island is directed more southern in comparison to West Java and East Java. Central Java orogenic physiography was formed by two main mountainous pathways, called The Southern Serayu Mountains and The Northern Serayu Mountains and both which are sedimentary basins. Active tectonic during sedimentation process in the western part of Serayu Basin, there was an collapse intensively between older rock due to the increase and decrease of basement. The slumping indicated is related to toe thrust as in the eastern part of the basin (figure 1). The presence of toe thrust can be a hydrocarbon structural trap. These due to the two Paleogene main faults are called the Muria-Kebumen Fault, left lateral, trending southwest-northeast and the Pamanukan Cilacap Fault, right-lateral, trending northwest-southeast, these faults passed through Central Java and separated in the northern then met in the southern [1].

Figure 1. Paleogene main faults: The Muria-Kebumen fault trending southwest-northeast, Pamanukan Cilacap fault trending northwest-southeast [1].

Almost all of the northern Serayu Basins are filled turbidite deposits with flysch characters. These deposited when the strain in the back arc basin was formed by the displacement of the through towards the ocean or the trench rollback with intensive deformation which is controlled by rapid and constantly active in Late-Early Miocene [2]. Sedimentation due to the influence of active tectonics during the Miocene has an impact on space accommodation changes form the basin one of which is sea level changes. Sea level changes are strongly associated with depositional environment during the sedimentation process. The North Serayu Basin consists of Neogene rocks (Miocene-Pliosen) from the oldest to the youngest known as Pemali Formation, Halang Formation, Rambatan Formation, Kumbang Formation, Tapak Formation, and kalibiuk Formation (figure 2). Monotonous beds of grey-blue and grey-green globigerina marls are characteristic that the layers comparable to the Pemali Formation.
Rambatan Formation are divided into two parts: the lower part is characterized with interbedded sandstone and limy claystone, intercalated conglomerate, marl, and limestone. The upper part is dominated limy claystone, intercalated limy sandstone locally and marl. These formation was deposited by Miocene- Early Pliocene (N14-N18) turbidity current mechanism from inner-outer fan system based on planktonic foraminifera [3]. From the other paper it was explained that Rambatan Formation is a source rock has TOC oscillate 0.43 %-1.2 % with kerogen type III coastal provenience [4]. Appearance Halang Formation in the studied area are characterized by coarser grained sandstones with abundant planktonic foraminifera including *Globogerinoides extremus*, *Globorotalia plesiotaumida*, *Globorotalia tumida*, and clearly turbidite type classic sedimentary structures such as graded bedding, convolute lamination, flute cast, and slump. The overlying conformable Halang Formation is Kumbang Formation with open marine sediment deposit but in the other side has unconformity. Andesite breccia and volcanic deposits such as lava and dike are characteristic of Kumbang Formation. Tapak Formation overlying conformable of Kumbang Formation was characterized by marl, limestone, tuffaceous sandstone, shale, and fine grained sandstone that showing lagoonal environment, in some places planktonic foraminifera were found which showed a transgression phase in the upper Pliocene. Kalibiuk Formation was composed of argillaceous clay, shale abundant molusca, sandy marl, intercalated calcarenite, tuffaceous limy sandstone, current ripple sandstone and andesitic conglomerate with plants fossil. In the several places were found pyroclastic material that shows the volcanic activity influence. Some macrofossils in this formation are *Balanus, Crabs, Achinoderms, Gastropods*, and *pelecypods*. The age of Kalibiuk Formation is the upper part Lower Miocene or the lower part Upper Miocene and they has neritic-litoral environment [5]. The location type of Kalibiuk Formation at Kalibiuk River, embranchment Glagah River.

![Figure 2. Regional stratigraphy of Central Java, box is stratigraphy in the studied area [6].](image-url)
2. Method
Measuring 4 sections on the base of river then observe detailed outcrops in each meter, both texture and sedimentary structures. During these observations stratigraphic succession of the studied area was also observed. 14 Samples were selected for analysis of both porosity and permeability based on catastrophic changes. Megascopich and microscopic descriptions were carried out for each sample to determine qualitatively both composition and porosity permeability. Porosity permeability value were obtained using helium porosimetry. Almost entirely samples analyzed are very fine-fine grained turbiditic sediments, while one sample is coarse grained turbiditic sandstone.

3. Result and discussion
Many characters presented by gravity flow sediment and has some key features that can be seen in outcrops. The Halang Formation is deposited by high-sinuosity channels and developed as a mud-dominated sub-marine fan system [7]. Detailed stratigraphic measurements carried out on the base of Ciseureh river and Rambatan river namely Rambatan and Halang Formation from centimeter scale were identified 3 facies associations: supra fan lobes, basin plain deposits, and shelf margin. Shelf margin environment represented by sandy siltstone, which are intercalated with very thin-to-thin-bedded, very fine to fine-grained sandstones with parallel and current ripple cross laminations, commonly intensely bioturbated and locally show hummocky cross-stratification [8].

Foraminifera was examined and was conclude that the study area interpreted as inner-middle fan are characterized by deposition of Middle Miocene-Late Miocene interbedded marl-limy sandstone with lamination and ripple intensively repetitive, thus marl is commonly interbedded with turbidites and could serve as both source rock and seals.

3.1. Porosity permeability value
In this case porosity uses units of percentage and permeability using milidarcy. A rock is considered to have potential as a reservoir if it has good porosity and permeability. Reservoir quality is assessed amount of interconnected porosity exists, porosity type, and their porosity distribution [9]. Horizontal helium porosity were estimates the porosity value oscillate between 2% - 30.3%, then the permeability value from 0.005 mD – 76 mD (figure 3). According to their sedimentary structure and porosity permeability values, samples divide to 3 groups which is group 1 are limy sandstone graded bedding abundant foram with porosity 2% and permeability values 0.005 mD, limy sandstone upper lamination sedimentary structure with porosity 5.7 %–11.9 % and permeability 0.112 mD – 5.71 mD, convolute limy sandstone with porosity 17.3 % and permeability 0.43 mD. Group 2 are cross lamination sandstone with porosity 22.1 % and permeability 0.739 mD, graded bedding sandstone with porosity 11.9 % - 23.1 % and permeability 8.31 mD - 22 mD. Group 3 are lower lamination sandstone with porosity 7.9 % and permeability 19.2 mD, wavy, trace fossil, and slump sandstone with porosity values 2% – 30.3% and permeability 19.2 mD – 201 mD (figure 4). Permeability and porosity are primary factor to determining the potential reservoir, but gravity flow sediment have varies value of porosity and permeability.

| Sample | Code | Sedimentary Structure | Permeability (mD) | Porosity (%) |
|--------|------|-----------------------|------------------|--------------|
| UFL1   | K2A  | Upper Lamination      | 0.02            | 2.0          |
| UFL2   | K2B  | Correlation           | 0.04            | 2.0          |
| UFL3   | K2C  | Gaudy                 | 0.06            | 2.0          |
| UFL4   | K2D  | Lower Lamination      | 0.08            | 2.0          |

Figure 3. Porosity (%) permeability (mD) values, sedimentary structure, lithology, and sedimentary texture from 14 selected outcrop.
Figure 4. Porosity permeability values are separated based on type of sedimentary structure devide to 3 groups, group 2 and group 3 to be consider as reservoir.

3.2. Gravity sediments texture
In general, gravity flow sediments are interesting for analysis, especially porosity and permeability which are relatively varied, one of the variations is influenced by grain sorting [9]. The samples was identified almost entirely have moderate sorting, very fine-fine grained, and subrounded-rounded grains, mineral containing quartz and calcite, and. The sample was identified with microscope polarization was found in the location 1 section 1 Ciseurc river, which has mud supported with dominant point contact features. Sorting is relatively good with rounded-subrounded grains. The present porosity is intergranular primary porosity from petrography analysis is 1% and secondary porosity 2% (Figure 5). Characterization of the sediment layer which are mud dominated interbedded with fine sandstone has the type of intergranular porosity and dissolution, is characteristic of the gravitational sediment in this studied area.

Figure 5. Stratigraphic succession and thin section that explains porosity type and value, the biggest permeability porosity value is limy sandstone with slump bedding sedimentary structure which is porosity = 24.7% and k = 201mD, while limestone abundant foram with graded bedding sedimentary structure has the smallest porosity permeability value with porosity = 2% and k = 0.005mD.
4. Conclusion

8 samples from 14 samples limy sandstone are likely to be good reservoirs. Selected slump are generally very fine- to fine-grained sandstone, whereas medium-grained sandstones are extremely rare and mostly seen on ‘slope’ fan facies which is the highest porosity and permeability. Based on field data that has been analysed both megascopically and microscopically concluded that is divided into 3 facies, namely supra fan lobes, basin plain deposits, and shelf margin. The lowest and highest porosity permeability besides being influenced by sorting can also be separated based on the visible sedimentary structure. Good porosity permeability are found in the shelf margin which is concluded based on the sedimentary structure and benthic microfossils with \( k > 10 \text{ mD} \) and \( \text{por} > 10\% \) and belong to group 3. Sandstone graded bedding, cross laminar sandstone, and lower lamination sandstone with porosity \( 11\%-28\% \) and \( k \) \( 0.74 \text{ mD} \) – \( 22 \text{ mD} \) into the group 2. Upper lamination sandstone, convolute sandstone, and graded bedding abundant foram with porosity \( 2\%-18\% \) and \( k \) \( 0.01 \text{ mD} \) – \( 8.31 \text{ mD} \) into the group 1. Group 3 to be consider to potential deep marine sediment reservoir.

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