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Rock Mineralogy Analysis of Airbenakat Formation to Map the Characteristics of the Reservoir Rocks in each Depositional Environment

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ABSTRACT

The Airbenakat Formation is a sandstone reservoir which is one of the oil reservoirs located in Sumatra and is part of the South Sumatra Basin. The mineral composition of the sandstone reservoir in the Airbenakat Formation consists of quartz minerals as rock grains, clay as matrix and is often identified as cement, while carbonate as rock cement. Based on lithofacies observations, the depositional environment of the Airbenakat Formation consists of: Volcanic Alluvial Fan, Lake, Braid Bar, Braided Channel, Braid Deltaic Environment, Mud Flat, Tidal Sand Bar, Tidal Environment, Shallow Sea, and Deep Sea. This research was conducted on 2 (two) oil fields, namely MRP and TPN which have different depositional environments but are included in the Airbenakat Formation as part of the South Sumatra Basin.

The analyzes used in this study include X-Ray Diffraction (XRD) analysis, petrography, and Scanning Electron Microscopy with Energy Dispersive X-Ray Spectroscopy (SEM/EDX). Analysis of the mineralogical content of the Airbenakat Formation will assist to determine the performance of chemical injections such as injection of anionic surfactant. The anionic surfactant used for chemical injection in Airbenakat Formations will be optimal if the content of smectite and calcite minerals can be ascertained. The presence of smectite and calcite minerals will affect the results of anionic surfactant injection. This research shows the results of anionic surfactant injection on the presence of smectite and carbonate in the injected core.

Keywords: airbenakat formation; depositional environment; smectite; calcite; surfactant injection

I. INTRODUCTION

Mineralogical content is formed from the depositional environment of the reservoir which occurred over millions of years. Different depositional environments cause the mineralogical content of reservoir rocks to be very different. The Airbenakat Formation is in the South Sumatra basin. The Airbenakat Formation was deposited in the regression phase of the middle Miocene age. In general, the Airbenakat Formation is composed of interbedded clay, sandstone and silt which contain glauconite and are rich in foraminifera. This condition can be seen in the rock minerals of the TPN Field. A different mineralogical analysis was found in the MRP Field where the productive layer is the Airbenakat Formation. The MRP field is a field that produces oil and gas located in the South Sumatra basin which is included in the back arc basin. Reservoir rock observations carried out found volcanic rocks as reservoir rocks in the MRP field, where the results of the observations showed the presence of light gray tuff lithology with a parallel laminated structure. Figure 1 shows the location of this study.

The location of the reservoir samples can be seen in Figure 2. Location 1 is the MRP Field and Location 2 is the location of the TPN Field reservoir rocks. Deposition of regression from the upper part of the Gumai Formation marks the initiation of the uplift of the Barisan High in the Middle Miocene. The regressive nature of the Airbenakat Formation indicates that the Slanting Tectonic system began as a result of the subduction of the Indian Ocean Plate towards the Sunda Shelf. This tectonic is the Syn-Orogenesa stage where the Syn-Orogenesa deposits are the Airbenakat Formation which was deposited during the Middle Miocene to Pleistocene. The Airbenakat Formation changes its depositional environment upwards to become shallow marine (Figure 3). The Airbenakat Formation changes its depositional environment upwards to become shallow marine.

Chemical injection, especially surfactant injection, is one method to achieve the target of increasing oil production proposed by the government to be carried out by oil companies. The study of mineral content in reservoir rocks is very helpful in understanding the performance of anionic surfactant solutions used for sandstone reservoirs. This research will discuss the presence of the minerals calcite and smectite (montmorillonite).

The presence of calcite and smectite (montmorillonite) minerals in reservoir rocks can affect a decrease in the performance of anionic surfactant injection for sandstone reservoirs.

In determining the classification of sandstone, there are several parameters that need to be considered, such as the type of sandstone (arenite or wacke), grains, matrix, and cement. Parameters in determining sandstone composition can be seen from stable or unstable grains (quartz, feldspar, and lithic fragments). The matrix in the form of clay and mica is rock alteration or rock mineral breakdown. The cement contained in sandstone varies greatly, consisting of silica minerals (quartz, feldspar and zeolite), carbonates (predominantly calcite, dolomite and siderite in small amounts), iron oxides (hematite, limonite and goethite) and sulfates (anhydrite, gypsum and barite). The parameters in determining the type of sandstone are arenite (clean sand) or wacke (dirty sand). Sandstone classification can be divided into quartz, arkose, lithic sandstone and greywacke sandstone (Gilbert, 1982 and Pettijohn, 1987). In determining the sandstone classification, it is analyzed by looking at the QFL plot (Quartz, Feldspar and Lithic). Webb, 2012, conducted research by analyzing minerals using XRD, SEM and EDS. The aim is to observe the influence of rock minerals on sandstone reservoirs where Alkali-Surfactant-Polymer (ASP) injection will be implemented. Thin section analysis and XRD show the presence of clay, where this mineral will be a consideration because it will influence the application of EOR method used.

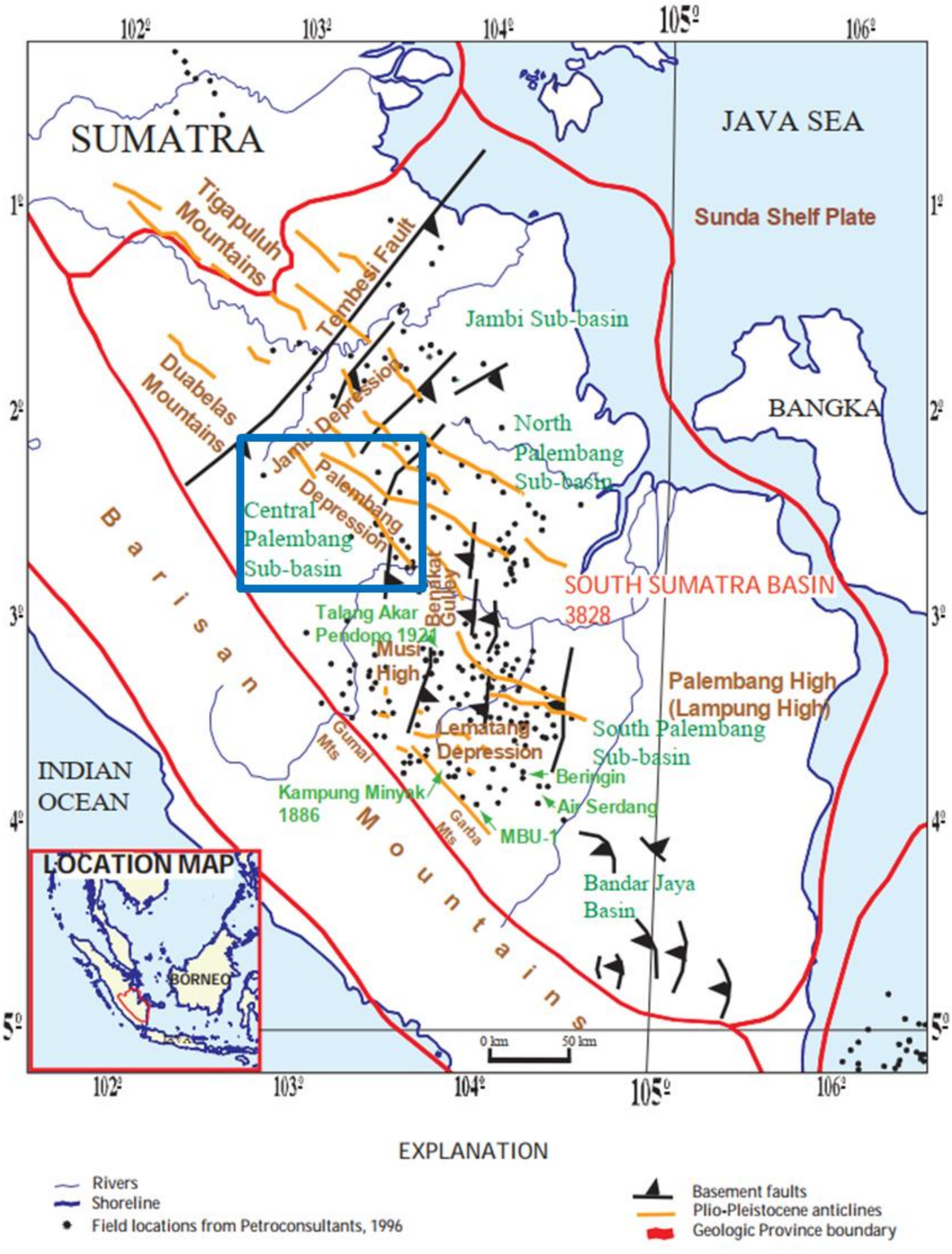

Figure 1. The location of MRP field and TPN field

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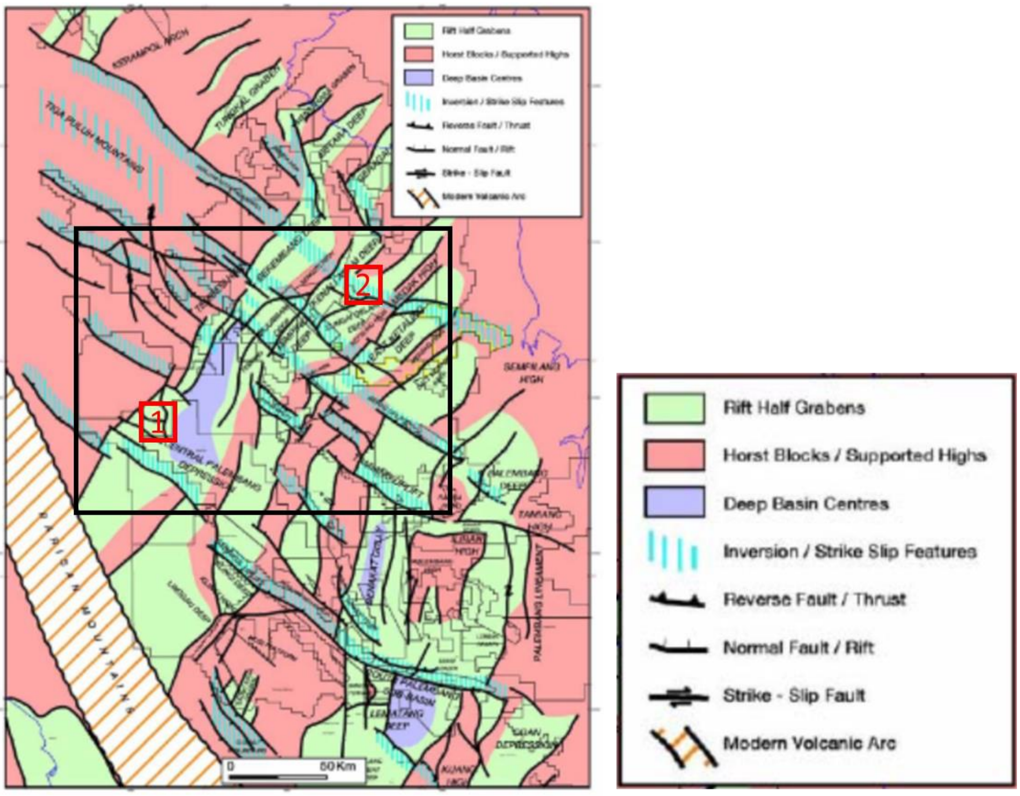

Figure 2. Jambi Sub Basin Structure Map (Ginger & Fielding, 2005)

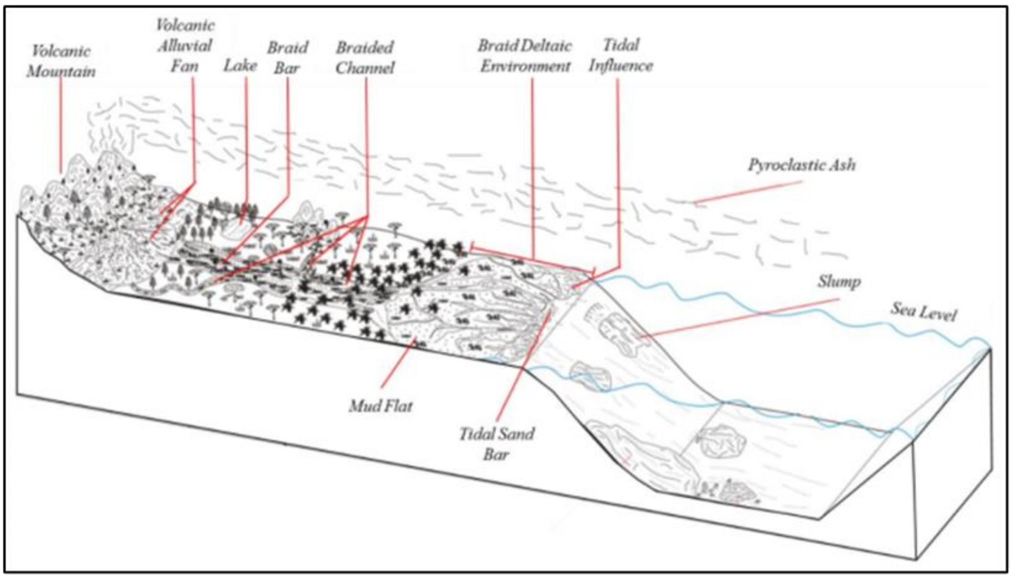

Figure 3. Airbenakat Formation Depositional Environmental Model

Marhendrajana and Idea (2016) conducted research with the aim of knowing the influence of minerals and sandstone grain arrangement on the injection of anionic surfactants and knowing the types of minerals that influence the performance of anionic surfactants. Research shows that carbonate cement fills the spaces between granules which causes reduced porosity and even covers the pores between granules so that they are unable to produce oil. Research shows that there is brown clay and carbonate cement that fills the pores between rock grains which causes interlocking porosity so that surfactant injection is not successful in producing oil.

High smectite content will lead to large adsorption. The anionic surfactant solution will lead to high adsorption of carbonate because the calcite mineral can cause precipitation (Sheng, 2011). The smectite (montmorillonite) content in brine-based surfactant injection must be low (Sheng, 2011) because the presence of H_2O and cations in the smectite structure layer can cause exchange capacity so that the smectite is hydrated and forms a larger structure size or swelling (Pettijohn, 1973). Injection of an anionic surfactant solution will cause high carbonate dissolution in Graywacke sandstone because the binding mineral calcite can cause precipitation (Sheng, 2011).

II. METHODS

In this research, several tests were carried out to analyze the presence of calcite and smectite minerals in the reservoir rock samples used. The analysis carried out was by carrying out XRD tests, thin sections, and SEM-EDS. This mineralogical analysis was carried out to confirm the presence and observe the changes that occurred in reaction with carbonate cement (calcite) and smectite (montmorillonite) after injection of alkyl carboxylate surfactant.

Sample preparation was carried out for sizes 100 – 200 mesh. XRD profiles can provide qualitative and semi-quantitative data on the rock samples tested. Observational analysis of thin sections was carried out at 5x, 10x and 25x magnification. The results of analysis from thin sections show the type of sandstone, grains, matrix, cement, and porosity formed. Calcite analysis is carried out by adding alizarin red, where adding alizarin red to the cut sample will produce a red color if it reacts with calcite. This helps in observing incisions and analyzing the presence of calcite as cement and/or rock matrix. The addition of blue dye was carried out to analyze the porosity formed when the sample was cut. The blue color in the cut confirms the porosity formed in the cut sample. The results of thin section analysis help confirm the minerals contained in the XRD test and obtain information from the surface of the rock being analyzed. SEM-EDS analysis was carried out using a Jeol IT300 with a JED-2300 series EDS detector. The magnification used ranges from 75x – 2000x. The samples used for analysis were incision samples with a thickness of 2-3 ml. From SEM photos, a topographic image of the section sample is obtained, and this helps confirm the results of thin section analysis. Meanwhile, the results from EDS can confirm the minerals contained in the cut samples which have previously been analyzed petrographically. By carrying out XRD, Thin Section, and SEM-EDS analyses, the analysis result was good enough to validate the calcite and smectite minerals in the core samples.

The rocks analyzed are reservoir cores, both TPN cores and MRP cores, where the MRP field reservoir cores are obtained from SWC (Side Wall Core).

III. RESULTS AND DISCUSSION

This research was carried out by analyzing sandstone samples from outcrops of the Airbenakat Formation and reservoir samples of the Airbenakat Formation from oil fields in Central Sumatra. The MRP Field Reservoir core was chosen because anionic surfactant injection using the TPN field reservoir core produced a recovery factor of 9%, where the same surfactant injection carried out on the Berea sample produced a recovery factor of 20% (Marhaendrajana & Idea, 2016).

The sample cores used for the MRP Field are Core M-1 and M-8. Core M-1 is the core from the MRP-56 well which was taken at a depth of 3202 ft and Core M-8 is the core from the MRP-63 well which was taken at a depth of 3138 ft. Thin-section analysis was carried out on the M-8 core to confirm the mineralogy contained in the core where the analysis was carried out before surfactant injection. Meanwhile, for the M-1 core, a thin section analysis was carried out after surfactant injection because the M-1 core is physically included in the category of cores that can be injected with surfactant.

The results of the XRD analysis for M-8 showed the presence of 8% smectite minerals, 9% illite and 7% kaolinite, while 54% quartz was present, and 10% calcite was detected. This section analysis of core M-8 is shown in Figure 4. The analysis in Figure 4 shows that core M-8 is a Feldspathic Wacke (Gilbert, 1982) where a thin section shows sedimentary rock, sandstone, clastic texture, moderately sorted, closed packing. There are 60% grains consisting of quartz, plagioclase, potassium-Felspar, and biotite, which are angular in shape. The matrix consists of potassium-Felspar and 10% plagioclase. Cement is present in the form of 20% clay. The porosity is 10%, which is dominated by intergranular porosity due to dissolution.

The results of the XRD analysis showed the presence of clay minerals, namely smectite at 12%, illite at 4%, quartz at 58% and no carbonate minerals were found. Thin-section analysis can be seen in Figure 5. Analysis in Figure 5 shows that the sandstone core is Feldspathic Wacke (Gilbert, 1982). There are 60% grains consisting of quartz, plagioclase, potassium-feldspar, and biotite, with an angular shape. 10% of the matrix consists of potassium-feldspar and plagioclase. As much as 20% of cement consists of clay. There is a porosity of 10% which is dominated by intergranular porosity due to dissolution and micro-porosity. Igneous rock fragments are present due to the influence of volcanic activity from the Bukit Barisan Mountains.

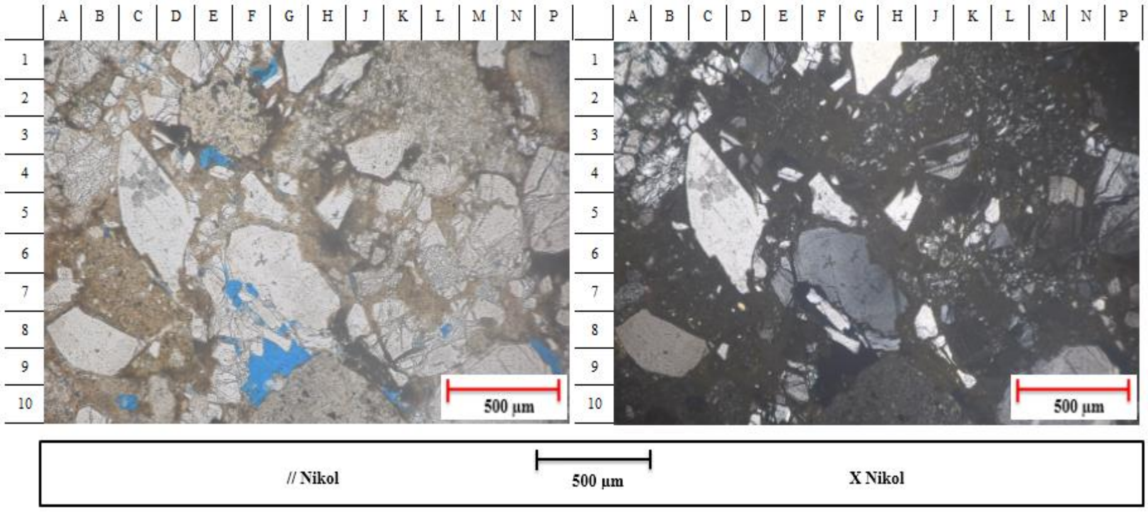

Figure 4. Photomicrograph core M-8 from MRP field

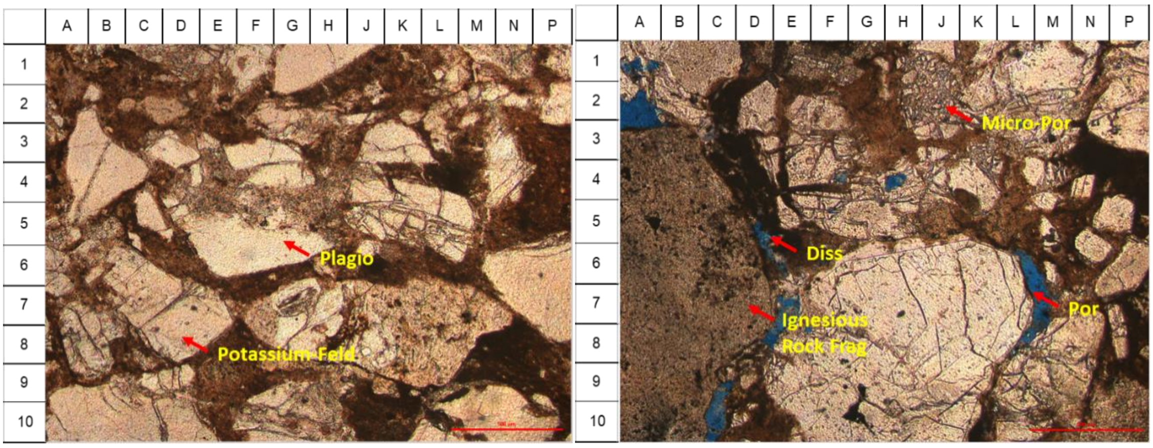

Figure 5. Photomicrograph core M-1 from MRP field

SEM-EDS analysis was carried out to confirm the presence of smectite from the XRD analysis results. Analysis results are shown in Figure 6. Analysis of Figure 6 shows that "A" indicates the presence of cement dominated by smectite and small amounts of calcite filling the pore cavity. The presence of calcite was confirmed from the EDS results at point "A".

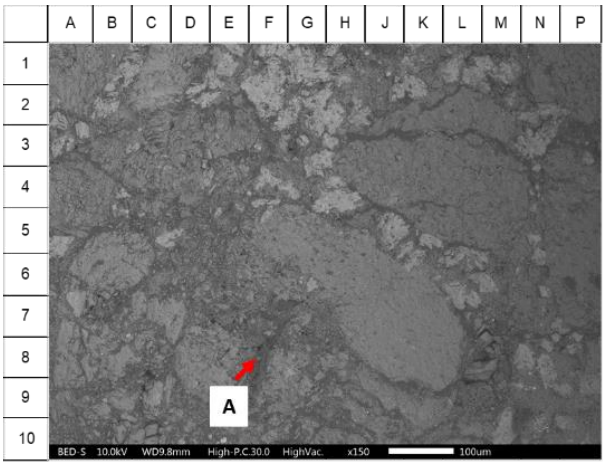

Figure 6. SEM-EDS result for core M-1

Combining XRD, Thin section and SEM-EDS analysis is very helpful in identifying and confirming the minerals that make up rocks. In thin section and XRD analysis, the mineral calcite (Ca^{2+}) was not identified in core M-1, whereas with SEM-EDS analysis, the presence of calcite (Ca^{2+}) was identified which filled the rock pores as cement.

XRD analysis of the TPN core shows the presence of montmorillonite at 3.6%, kaolinite at 5.3%, quartz at 52.4% and a combination of albite, calcian and ordered at 20.1%. Thin section analysis on TPN-A core after injection of anionic surfactant. Figure 7 shows the thin section analysis of TPN-A.

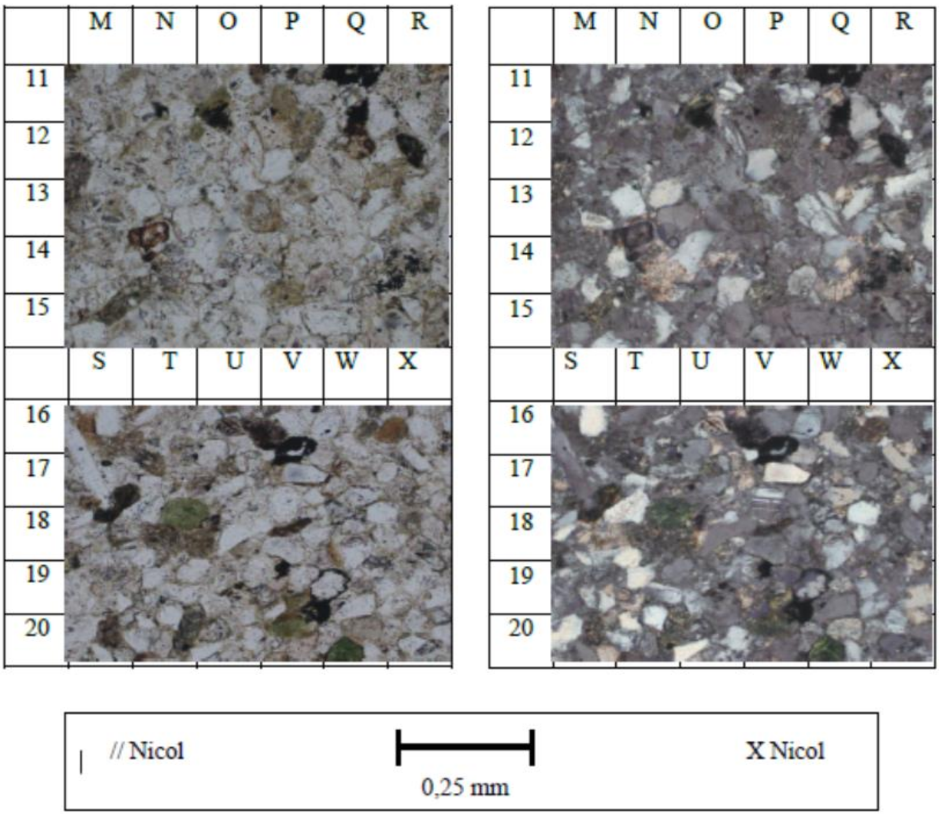

Figure 7. Photomicrograph core TPN-A

The TPN-A core is a core used for anionic surfactant injection where the coreflood results in that there is no incremental oil. Petrographic analysis of core TPN-A is a thin section of sedimentary rock, sandstone, clastic texture, medium-poorly sorted, open-packed (long contact), 70% of the grains consist of quartz, plagioclase and glauconite in rounded-to-angled shapes. The matrix consists of clay and quartz at 15%. Silica and carbonate cement by 10%. while the intergranular porosity is 5%. In Figure 6, we find indications of hydrocarbons filling the spaces between the grains. Characterized by black color on Plane Polarized Light (PPL) and Crossed Polarized Light (XPL) and does not resemble mineral on Q11 and W19. Carbonate cement fills the spaces between granules which causes the porosity to be reduced to 5%. Glauconite is a characteristic of minerals with shallow marine depositional environments or influenced by shallow seas.

The addition of alizarin-red to the TPN-A sample aims to observe calcite and dolomite in the core sample. Dolomite will not change color to red, where the red color indicates the mineral is calcite. The results of thin sections of TPN-A with alizarin-red are shown in Figure 8. From Figure 8 it can be analyzed that the petrography of core TPN-A (alizarin-red) is a thin section of sedimentary rock, sandstone, clastic texture, moderately sorted, open packed (long contact, point contact), 55% of the grains consist of quartz, round to angular in shape. The matrix consists of clay and quartz as much as 25%. Silica and carbonate cement are as much as 10%. while porosity of 10% is present as intergranular and intragranular porosity. From Figure 8, it is very clear that carbonate cement fills the spaces between grains which causes a reduction in porosity in the sandstone. On the other hand, Figure 9 shows there is additional porosity due to the change in carbonate cement from calcite to dolomite (J9). This addition was caused by a change in crystal shape to become smaller from calcite to dolomite which was indicated by no color change in the carbonate mineral when alizarin red was added. However, adding porosity is not effective because of the clay matrix and carbonate cement. So, the coreflood on the TPN-A core failed to remove oil trapped in the core due to the reaction of carbonate minerals with anionic surfactants.

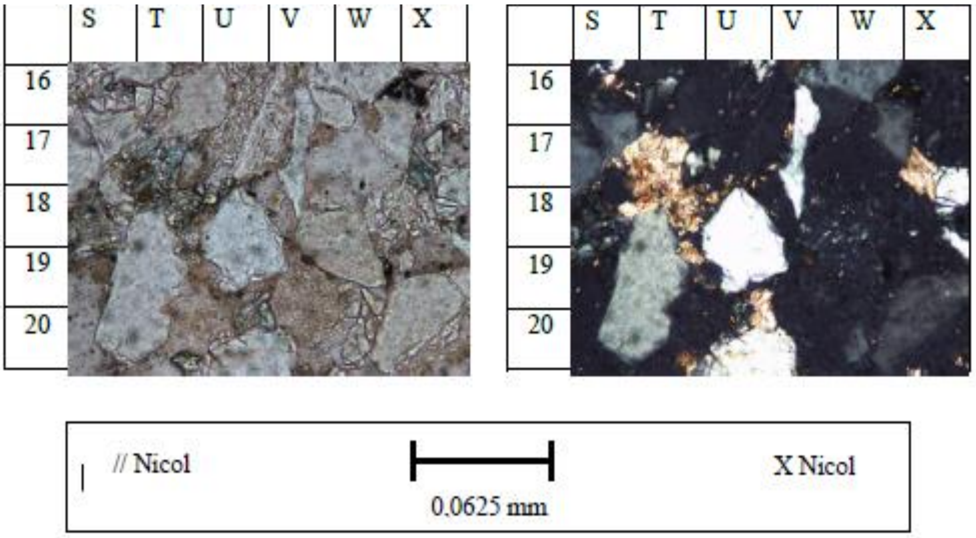

Figure 8. Photomicrograph core TPN-A (alizarin-red)

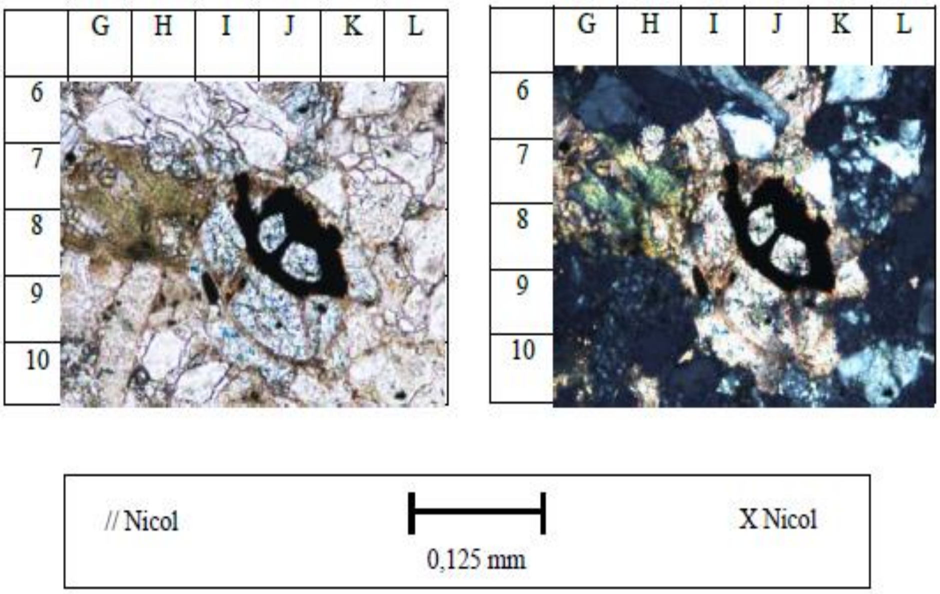

Figure 9. Photomicrograph core TPN-A (dolomitization)

SEM-EDS analysis was carried out to observe the presence of smectite minerals in the samples. The results of SEM-EDS analysis can be seen in Figure 10. The presence of smectite minerals in the TPN-A sample is shown from the SEM photo results in Figure 10. Meanwhile, EDS (Figure 11) shows the peak presence of Na and Al minerals as an indication of the presence of clay minerals, especially smectite (Na). The minerals Na and Al are the minerals that indicate smectite (montmorillonite). The presence of Ca and Mg elements indicates the presence of Calcite and Dolomite carbonate cement. The amount of clay and carbonate cement constituent compounds fills the matrix and covers the rock pores so that the small porosity and oil trapped in the core cannot flow out during the injection of anionic surfactants.

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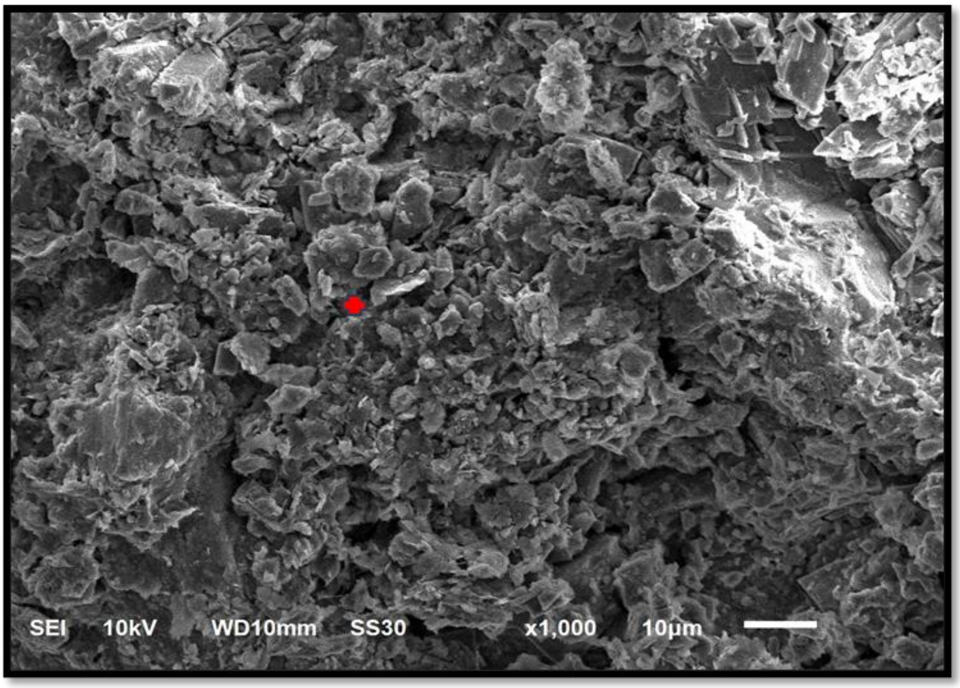

Figure 9. Photo SEM core M-38

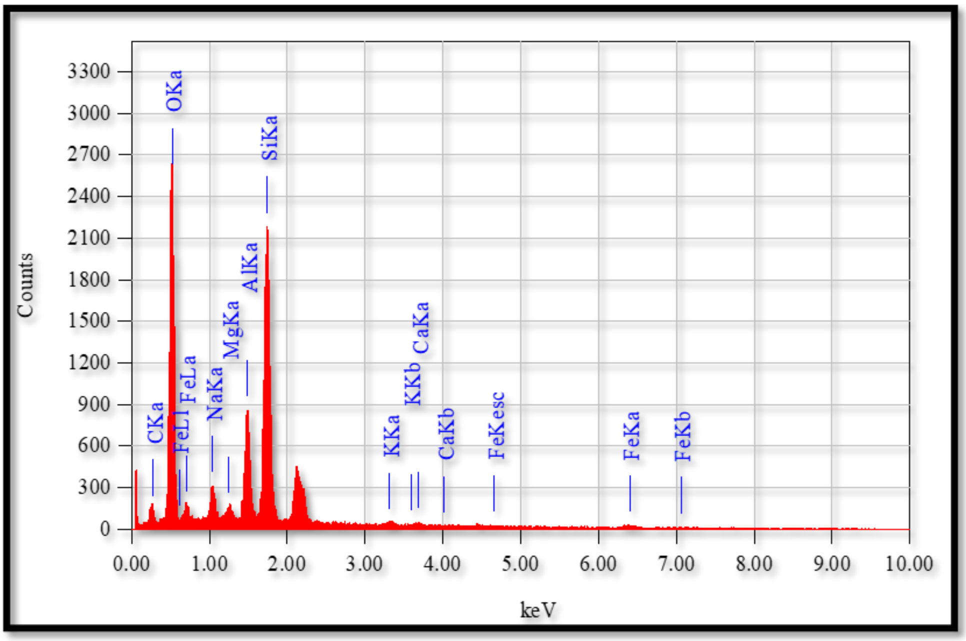

Figure 10. EDS analysis core M-38

Reservoir rocks in the Airbenakat Formation have different depositional environments (Figure 3). Petrographic analysis from the TPN and MRP Fields shows differences in rock minerals contained in the Airbenakat Formation reservoir samples. The depositional environment in the M Field is a volcanic alluvial fan depositional environment, while the TPN Field is a shallow marine depositional environment where the petrographic analysis carried out shows the presence of glauconite minerals as a marker of a shallow marine depositional environment. Field MRP and TPN Field are in the South Sumatra Basin with a sandstone reservoir of the Airbenakat Formation which was formed during the Middle Miocene. The western side (MRP Field) is affected by volcanic activity due to the Bukit Barisan Mountains (igneous rock fragments), while the Airbenakat Formation (TPN Field) is affected by a shallow marine depositional environment (Glauconite).

IV. CONCLUSION

Correct interpretation of the depositional environment of the Airbenakat Formation can assist in understanding the characteristics of rock minerals, especially smectite (montmorillonite) and carbonate. Where the presence of carbonate minerals can reduce the performance of the anionic surfactant solution and smectite content will lead to high adsorption.

The reservoir rock of the Airbenakat Formation in the MRP field is influenced by volcanic material where there are igneous rock fragments in the thin section M-1 analysis. Meanwhile, the TPN-A field reservoir rocks are influenced by shallow marine material where the green glauconite mineral was identified.

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