PETROPHYSICAL MODELING OF BATURAJA FORMATION IN ZAMAN FIELD USING WINLAND R_{35} AND FLOW ZONE INDICATOR

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ABSTRACT

Zaman Field is located approximately 150 km from Palembang City, in the South Sumatera Basin. The gas field comprises a carbonate reservoir that managed by the Pertamina EP located in Baturaja Formation. Baturaja Formation has a problem with heterogeneity and became necessary to perform the task of reservoir characterization in order to solve this problem. Thus, the objective of this study was to characterize the carbonate reservoir of Baturaja Formation by distributing petrophysical rock types, porosity, and permeability. Petrophysical rock type is one of the considered methods to understand reservoir heterogeneity. Winland R_{35} and flow zone indicator were performed to determine which method was more reliable for Zaman Field. Transform permeability was applied as a validation control in petrophysical rock type classification and Winland R_{35} method showed a better result than flow zone indicator method thus Winland R_{35} was utilised as an indicator of reservoir heterogeneity which divided the petrophysical rock type based on its pore throat size. This has produced four petrophysical rock types, which depend on specific porosity and permeability trends. Petrophysical rock type 1 was identified as having the biggest pore throat size, with petrophysical rock type has 4 the smallest pore throat size. Using a geostatic model it was possible to perform the distribution of petrophysical rock type, porosity, and permeability in the form of 3D model. As a result, it showed that petrophysical rock type 1 and 2 were well developed in the Upper Baturaja with estimated porosity values from 6.1 to 20% while permeability values from 2.2 to 13 md. Lower Baturaja was dominated by petrophysical rock type 3 and 4 with porosity values from 3.2 to 10.9% while permeability values from 0.1 to 0.2 md. The results of this study can be used as an additional data to improve reservoir description and the main input for a dynamic simulation and further development planning in Zaman Field.

ABSTRAK

Lapangan Zaman terletak kira-kira 150 km dari Bandaraya Palembang, di Lembangan Sumatera Selatan. Lapangan gas itu yang diuruskan oleh Pertamina EP, mempunyai sebuah reservoir karbonat dalam Formasi Baturaja. Formasi Baturaja berhadapan dengan masalah keheterogenan dan dengan itu, pencirian reservoir terpaksa dilaksanakan untuk menyelesaikan masalah itu. Objektif kajian adalah untuk mencirikan reservoir karbonat dalam Formasi Baturaja dengan memperincikan jenis batuan, keliangan, dan kebolehtelapan. Jenis petrofizik batuan ialah satu daripada kaedah yang dipertimbangkan untuk menyelesaikan heterogeniti reservoir. Kaedah Winland R_{35} dan penunjuk zona aliran telah dilaksanakan untuk menentukan kaedah yang lebih sesuai untuk lapangan Zaman. Kebolehtelapan jelmaan digunakan sebagai kawalan pengesahan dalam pengklasifikasian jenis petrofizik batuan dengan kaedah Winland R_{35} menunjukkan hasil yang lebih baik berbanding kaedah penunjuk zona aliran. Oleh itu, kaedah Winland R_{35} digunakan sebagai penunjuk keheterogenan reservoir yang menjelaskan jenis petrofizik batuan berdasarkan saiz bukaan liang. Hasil kajian menunjukkan empat jenis petrofizik batuan masing-masing dengan kecenderungan tertentu terhadap keliangan dan kebolehtelapan. Jenis petrofizik batuan 1 dikenal pasti mempunyai saiz bukaan liang yang paling besar, dengan jenis petrofizik batuan 4 memiliki saiz bukaan liang yang paling kecil. Menerusi penggunaan model geostatik, perincian jenis petrofizik batuan, keliangan, dan kebolehtelapan boleh dilaksanakan dalam bentuk model 3D. Hasil uji kaji menunjukkan bahawa jenis petrofizik batuan 1 dan batuan 2 telah terbentuk dengan baik dalam Formasi Baturaja Atas, dengan nilai keliangan masing-masing dari 6.1 hingga ke 20% manakala kebolehtelapan dari 2.2 hingga ke 13 md. Formasi Baturaja Bawah didominasi oleh jenis petrofizik batuan 3 dan batuan 4 dengan nilai keliangan masing-masing dari 3.2 hingga ke 10.9% manakala kebolehtelapan dari 0.1 hingga ke 0.2 md. Hasil kajian boleh digunakan sebagai data tambahan untuk meningkatkan pemeriksaan reservoir dan juga sebagai input utama untuk penyelakuan dinamik dan perancangan pembangunan selanjutnya di lapangan Zaman.

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LIST OF ABBREVIATIONS

GIIP	-	Gas initially in place
GR	-	Gamma ray readings
OOIP	-	Original oil-in-place
SP	-	Spontaneous potential log readings
RQI	-	Reservoir quality index
NPI	-	Normalized porosity index
FZI	-	Flow zone indicator
DRT	-	Discrete rock type
BRF	-	Baturaja Formation
CALI	-	Caliper log
BS	-	Bit size log
HLLD	-	Lateral log deep resistivity
HLLS	-	Lateral log shallow resistivity
RXOZ	-	Invaded zone resitivity
RHOZ	-	Formation density
TNPH	-	Thermal neutron porosity
DT	-	Delta t (sonic log)

LIST OF SYMBOLS

a	-	Tortuosity factor
B_{gi}	-	Gas formation volume factor
B_{oi}	-	Oil formation volume factor
C	-	Permeability constant
D	-	Porosity constant
E	-	Irreducible water saturation constant
GR_{clean}	-	Gamma ray log minimum value
GR_{shale}	-	Gamma ray log maximum value
I_{sh}	-	Shale index
k	-	Permeability
m	-	Cementation exponent
R_{35}	-	The calculated pore throat radius at 35% mercury saturation in a mercury porosimetry test
R_{sh}	-	Resistivity uninvaded zone of shale
R_t	-	Resistivity uninvaded zone
R_w	-	Formation water resistivity
S_h	-	Hydrocarbon saturation
SP_{clean}	-	Spontaneous potential log minimum value
SP_{shale}	-	Spontaneous potential log maximum value
S_w	-	Water saturation
S_{wirr}	-	Irreducible water saturation
V_b	-	Volume of reservoir
V_{sh}	-	Shale volume
ϕ_d	-	Density porosity log
ϕ_{dc}	-	Corrected density

ϕ_e	-	Effective porosity
ϕ_n	-	Neutron porosity log
ϕ_s	-	Sonic porosity log
ϕ_{sc}	-	Corrected sonic porosity
ϕ_z	-	Normalized porosity index
ρ_b	-	Rock density
ρ_{fluid}	-	Fluid density
ρ_{ma}	-	Rock matrix density

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CHAPTER 1

INTRODUCTION

1.1 Research Background

South Sumatera Basin is one of the most prolific hydrocarbon basins in Indonesia which is dominated by carbonate reservoirs within Baturaja Formation. However, these carbonate reservoirs are known with heterogeneous problem. It is due to deposition and diagenetic processes. Thus, as a potential hydrocarbon basin, the hydrocarbon exploration and production need to be optimized. One of the ways to optimize hydrocarbon exploration, development and production is by improving the understanding of reservoir properties such as porosity, permeability, water saturation, etc. These rock properties usually can be used to determine the reservoir quality. For example, a good reservoir is reservoir that has less clay content, smaller irreducible water saturation, larger porosity, and higher permeability. Permeability is considered as an important property of reservoir that has to be estimated. Thus, there are a lot of studies about permeability estimation with various methods. However, permeability estimation on well logs is normally done by correlating the permeability-porosity. In addition, reservoir properties are needed to build simulation model, which is a good model that can be used to predict the next field development or production behaviors (Sritongthae, 2016). Moreover, empirical relationship between permeability from core data and other petrophysical properties from well logs is a crucial part to build reservoir models (Jennings and Lucia, 2001).

There are many concepts which have been used to characterize the reservoir properties and one of them is rock type concept. Rock type is defined as units which is classified based on its characteristic such as it was deposited under alike geological conditions and/or has gone through same diagenetic alterations (Gunter *et al*. 1997). Besides, Sritonghae (2016) stated that petrophysical rock type is similar with rock type technique, but parameters that used are only the petropysical data such as porosity, permeability, water saturation. Interestingly, rock type can be applied in some knowledge for instance petroleum geology, petrophysic, reservoir and production engineering. In petroleum geology, rock type concept usually use in process to make depositional facies or lithofacies and build 3D stratigraphic reservoir modeling. In contrast to petroleum geology, petrophysicist divide rock types based on pore geometry, while reservoir and production engineers classify rock types based on flows unit which they use to make a reservoir simulation (Xu, 2013). Although from different background, the combination of these disciplines can lead to construct a reservoir model with exact petrophysical properties and can be used as a guide to predict hydrocarbon reserves. Thus, rock type is one of the concepts that can combine those knowledges.

One of the advantages of rock type is it can still be used even though there is limited or no direct measure of rock properties from core data. It is because this concept can do indirect measure from logs data. When rock type is proceed accurately, it can be utilized to estimate the formation permeability in un-cored intervals and wells, generate the trusty initial water saturation profile, and simulate an accurate reservoir dynamic behavior and production performance (Guo *et al*. 2007). Furthermore, rock type will assist in porosity and saturation height functions determination, so that 3D static reservoir models will be easier to compute.

As stated in the previous paragraph, one of the problems in carbonate reservoir in South Sumatera Basin is reservoir heterogeneity which was caused by deposition and diagenetic processes. Therefore, for the reservoirs which have heterogeneity, rock type concept can be an alternative to deal with it. It is because, using rock type, reservoir rocks will be classified based on its storage and flow capacities inferred from core measurements. Thus, it will be easier to determine the quality of reservoir. Moreover, creating a 3D model that is based on rock type can be one way to perform the relationship between heterogeneity and connectivity and also the distribution of reservoir properties within a formation. In addition, this concept can lead in determination of productive zones as a recommendation for the next wells to be drilled.

1.2 Problem Statement

Rock type can be used in various applications such as initialization, history matching, and well planning. Actually rock type can be divided into two namely core-based and log-based. By integrating core-based and log-based technique will give a much better result. It is because not all wells have core data for many reasons like horizontal wells, saving cost and time. On the other side, well logs have many weaknesses such as it gives indirect petrophysical measurement and erroneous readings. Thus, well logs need to be validated with core data to get better readings.

Furthermore, the fact that same lithofacies can have different reservoir properties such as porosity and permeability, due to diagenesis processes. Thus, rock type technique can be an alternative to deal with. There are several methods that can be applied on rock type concept. In addition, flow-zone indicator (FZI) and Winland R_{35} were applied for this study. These methods have proved to be applicable either clastic or carbonate reservoirs. There are limited numbers of study that compared these two methods and applied it in this study area. Thus, this study applied these methods to determine which method that suitable with the study area (named as Zaman Field).

1.3 Objectives of the Study

The main aims of this research are to characterize a carbonate reservoir and build 3D reservoir model. Therefore, specific objectives of the study are as follows:

1. To produce petrophysical rock type classification
2. To determine the suitable rock type method to be applied in Zaman Field
3. To determine the distribution of petrophysical rock type and reservoir properties

1.4 Scope of the Study

All the data was processed using Microsoft excel, interactive petrophysics (IP), and Petrel. The scopes of the study are as follows:

1. Calculating Vs_h, porosity, water saturation, and permeability based on well logs data.
2. Core rock type determination using FZI and Winland R_{35} methods.
3. Permeability transforms estimation from the relationship equation of porosity and permeability.
4. Built mathematical model from well log data for generating Winland R_{35} in un-cored intervals and wells to generate a synthetic petrophysical rock-type log.
5. Constructing 3D model based on its petrophysical rock type and petrophysical properties.
6. Model validation
7. Hydrocarbon reserves calculation.

1.5 Limitation of the Study

The study area is located in Prabumulih city, approximately 150 Km from Palembang city which is field of PT. Pertamina EP. This research has some limitations as follows:

1. There are very limited petrographic data, thus it is hard to define the microfacies in the study area.
2. Core data only available in two wells.
3. There is no Special core analysis data (SCAL) that provided, thus the classification of petrophysical rock type only based on porosity and permeability values.

1.6 Significant of the Study

As explained before, rock type is a reliable concept that can be used to deal with heterogeneity problem in reservoirs. Studies about this concept are conducted to reveal any more possibilities in producing hydrocarbon. Reaching the objectives of this research is expected to estimate hydrocarbon reserve. Moreover, by doing re-evaluation of reservoir characterization, we can see the prospects of field's development in determining the location of new potentially produced hydrocarbons.

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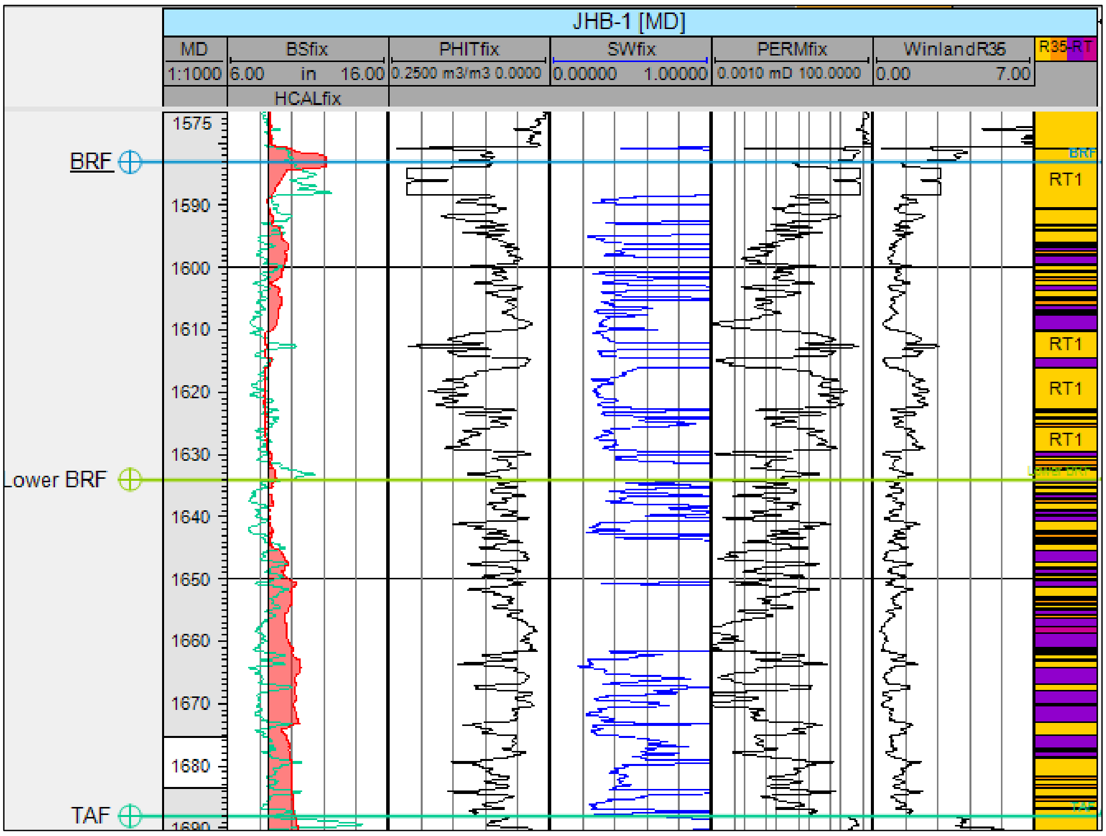
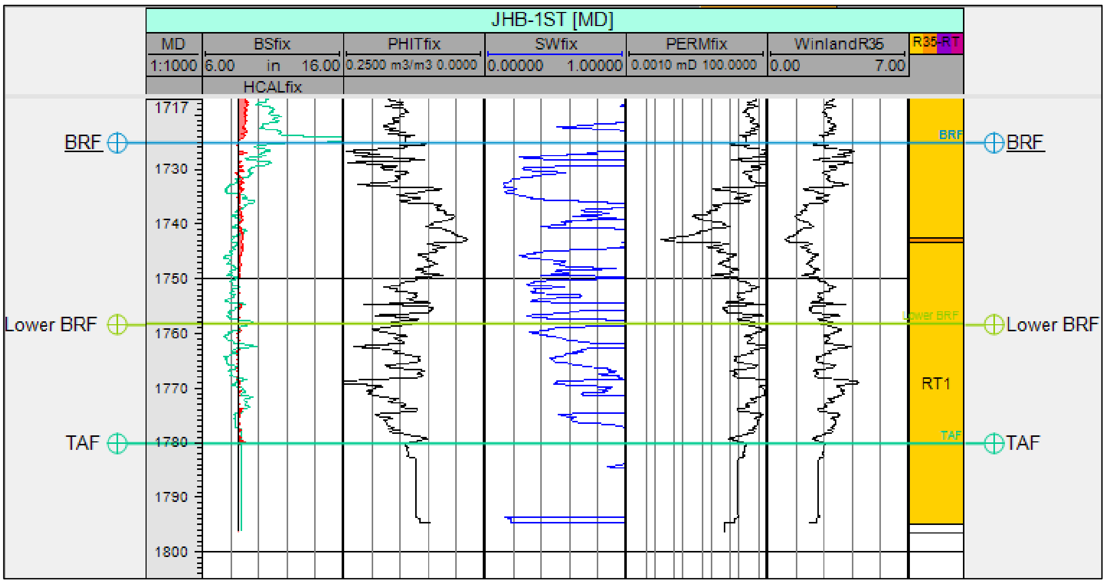
APPENDIX A1

Petrophysical Rock Type Distribution in Un-cored Intervals of JHB-1 Well



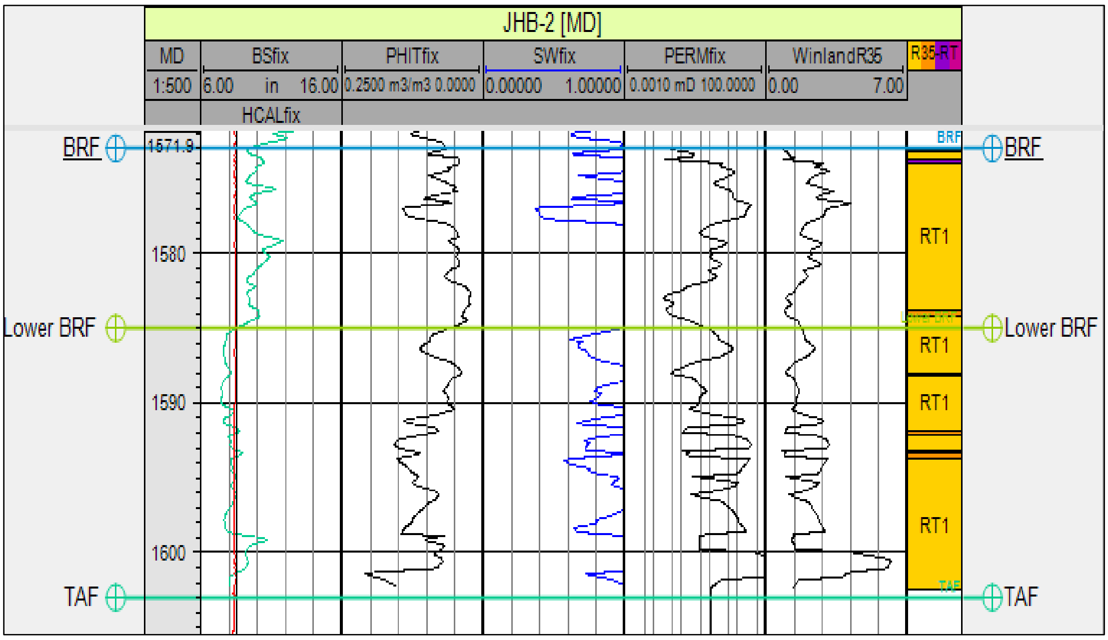
APPENDIX A2

Petrophysical Rock Type Distribution in Un-cored Intervals of JHB-1ST Well



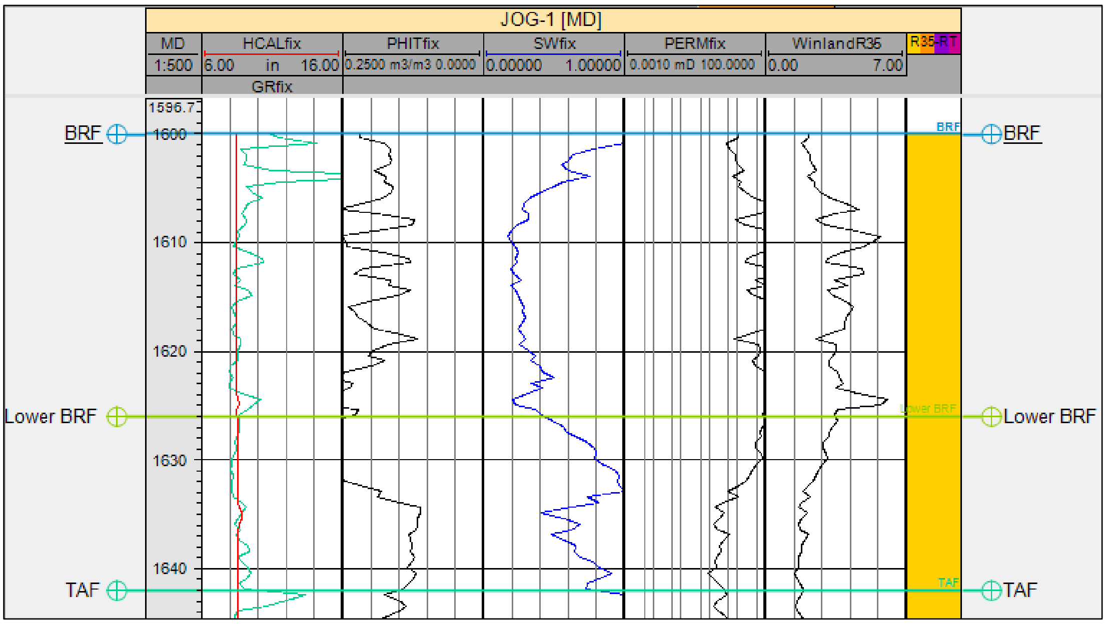
APPENDIX A3

Petrophysical Rock Type Distribution in Un-cored Intervals of JHB-2 Well



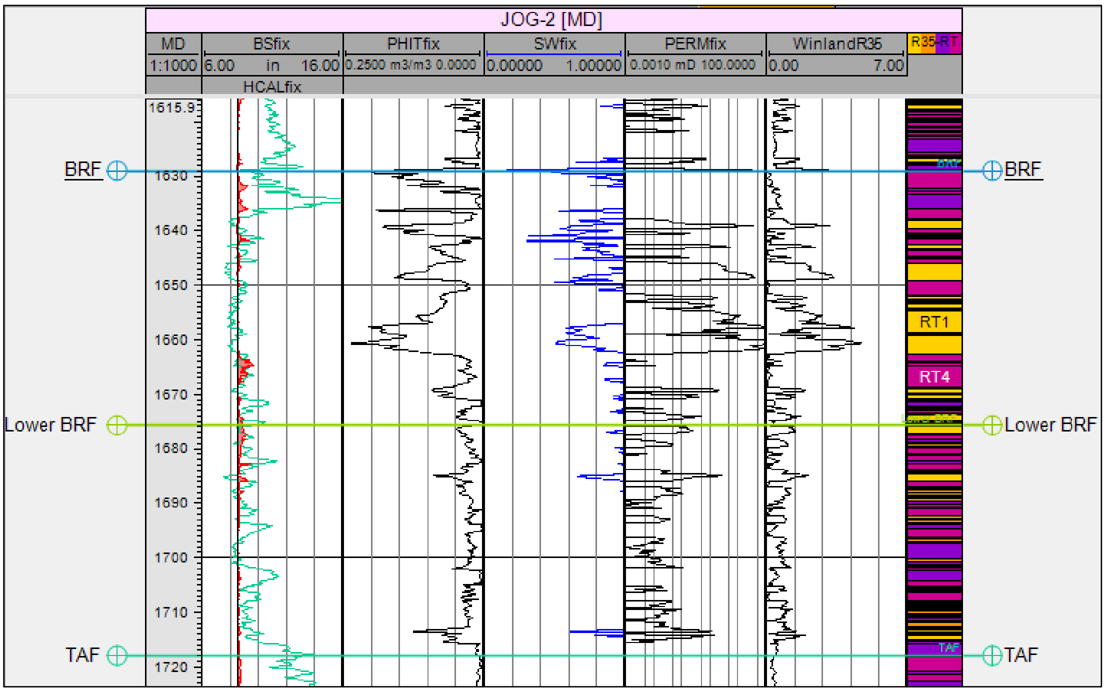
APPENDIX A4

Petrophysical Rock Type Distribution in Un-cored Intervals of JOG-1 Well



APPENDIX A5

Petrophysical Rock Type Distribution in Un-cored Intervals of JOG-2 Well



APPENDIX A6

Petrophysical Rock Type Distribution in Un-cored Intervals of JOG-3 Well