Aceh Int. J. Sci. Technol., 11(3) 220-230
December 2022
doi: 10.13170/aijst.11.3.24026

Aceh International Journal of Science and Technology
ISSN: p-2088-9860; e-2503-2398
Journal homepage: http://jurnal.unsyiah.ac.id/aijst

A Unique Volcanic Jatibarang Reservoir: Facies Characterization and Fracture Calculation

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Received : December 24, 2021
Received in revised from February 14, 2022
Accepted : January 13, 2023
Online : January 25, 2023

Abstract – Jatibarang structure, situated in Jatibarang low, one of the prolific sub-basin in the northwest Java basin, belongs to PT. Pertamina EP working area. One hundred seventy wells have been drilled, from which there were 56 production wells. Forty production wells were sunk on a volcanic reservoir. Since 1970, volcanic Jatibarang has faced disputed facies concepts, porosities heterogeneity, and permeability system. A fractured reservoir model was proposed. It was due to unique high-performance hydrocarbon in the early years, steeply depleted in the next 3 years, and flat over 20 years. A unique petrophysical method was developed with various explosives and effusive facies. This study proposes a new facies determination concept related to unavailable default petrophysical plots usually used in the clastic-carbonate reservoir. The new concept of formation evaluation attempts to distinguish the fractured vitric tuff reservoir and non-reservoir zone, which is both effusive lava and explosive product. Reservoirs differed from common clastic-carbonate, typically high gamma-ray reservoirs due to potassium feldspar composition. The fracture existence is reflected by a sonic overrunning density log aligned with a deep resistivity pattern. The width of the fracture apertures was measured, and spacing intensities were calculated. Finally, fracture permeability was estimated comprehensively to describe reservoir performance. Property models built with only sonic and triple combo have been debatable; however, advanced logging of JTB-211 has proven this accuracy method.

Keywords: Volcanic, Fractured reservoir, Vitric tuff.

Introduction

Jatibarang structure covers a 36 km2 area in Indramayu, West Java Provinces (Sendjaja & Kimura, 2020). This area belongs to Asset 3 Pertamina EP working area (Figure 1). The current status of Jatibarang structure suggests that 170 wells have been drilled, consisting of 56 production wells (40 wells from a volcanic reservoir), 23 injector wells, and 91 suspended wells. Jatibarang structure includes 640.986 million stock tank barrels (MSTB) original oil in place (OOIP) 551.032 MSTB from a volcanic reservoir. The cumulative production of Jatibarang structure was 86.180 MSTB in December 2013, with a 31% recovery factor. The remaining 86.979 MSTB was considered as "reserves." This fact suggests an excellent opportunity for Jatibarang structure development. Peak oil production occurred in April 1974 when produced 30.702 barrels of oil per day (BOPD). Jatibarang development drilling history started in 1968 when JTB-42 was the first well. This well was targeted at the Cibulakan formation. The volcanic formation was found at JTB-44 drilling in 1970. This formation produced 3750 BOPD in 1973.

The Volcanic Jatibarang formation is an excellent reservoir in PT. Pertamina EP Asset 3. This formation was drilled as the primary target until 2000—the previous drilling on this volcanic formation of JTB-60 and JTB-160. The JTB-60 was tested to produce 3300-4700 BOPD, and the JTB-160 was estimated to produce 2400-3200 BOPD. In 2001, Pertamina EP drilled JTB-205 as underbalanced operationally well with the volcanic layer as

doi: 10.13170/aijst.11.3.24026

the primary target but operationally failed. JTB-205 was the last volcanic target well in 2001. This well was justified as failed due to complicated operational problems, unsolved subsurface concepts, and pressure issues

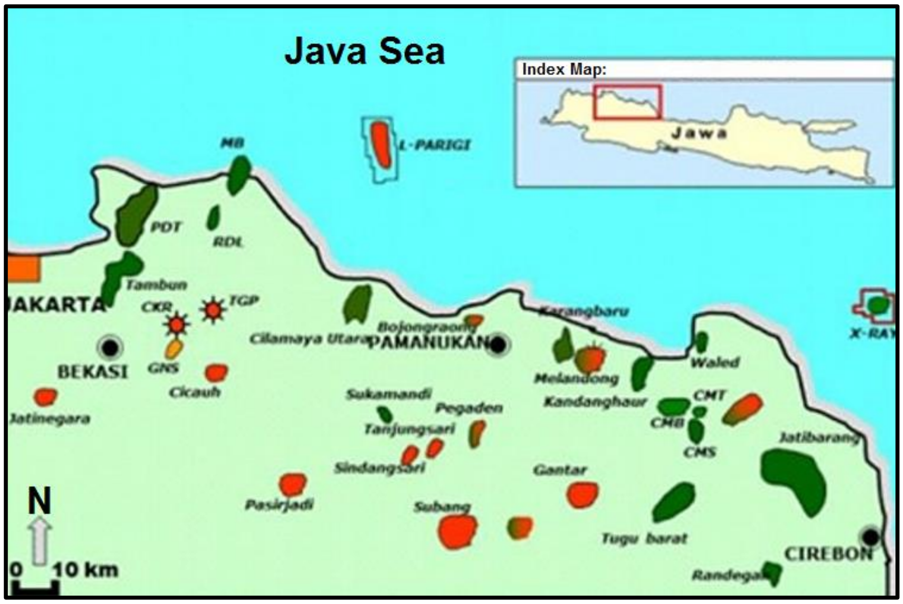

Figure 1. Location map of Jatibarang Structure (Pertamina, 2015)

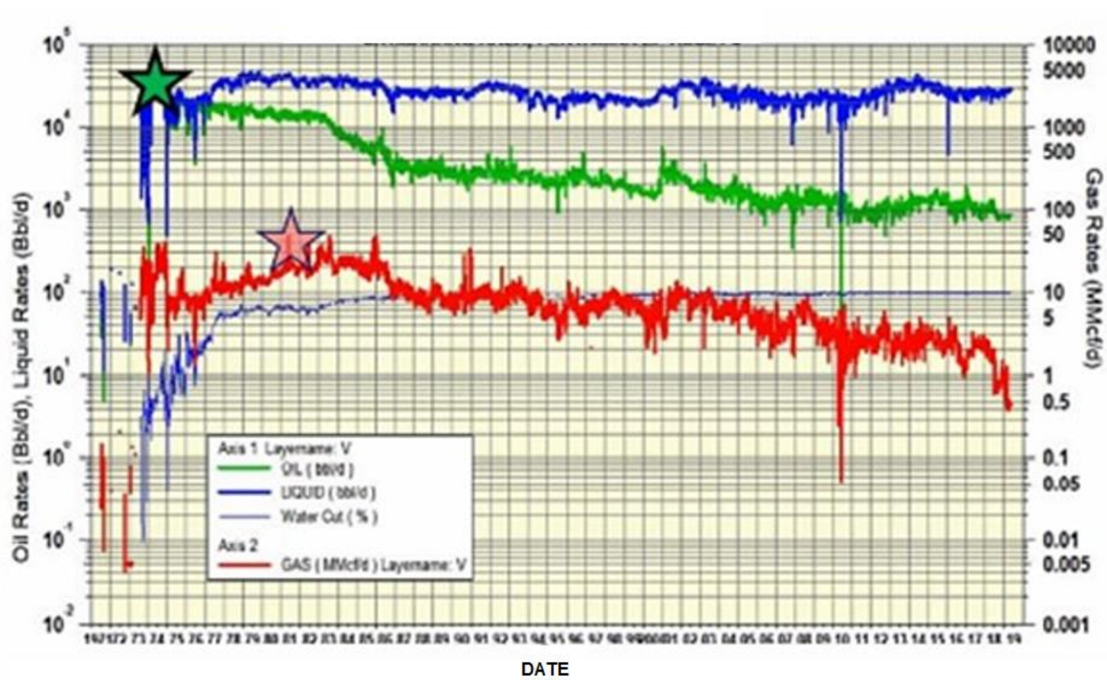

Figure 2. Production performance Volcanic Layer, Jatibarang Structure (Pertamina, 2015)

Jatibarang structure is geologically settled in Jatibarang low, northwest Java basin (Bishop, 2000). The northwest Java basin consists of high–low structures (Figure 3). This Jabarang structure comprises wide lithology varieties of the reservoir, from the metamorphic basement and basin infilling to post-rift sediment, clastic, porous or tight carbonate, marble(?), and volcanic rock.

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Penetrated to 2-3 km in the onshore area by thousands of wells, the drilling history provides information about the existence of the volcanic Jatibarang reservoir in the eastern part of the northwest Java basin only. In the western area of the Jatibarang structure, Eocene limestone was found in many wells.

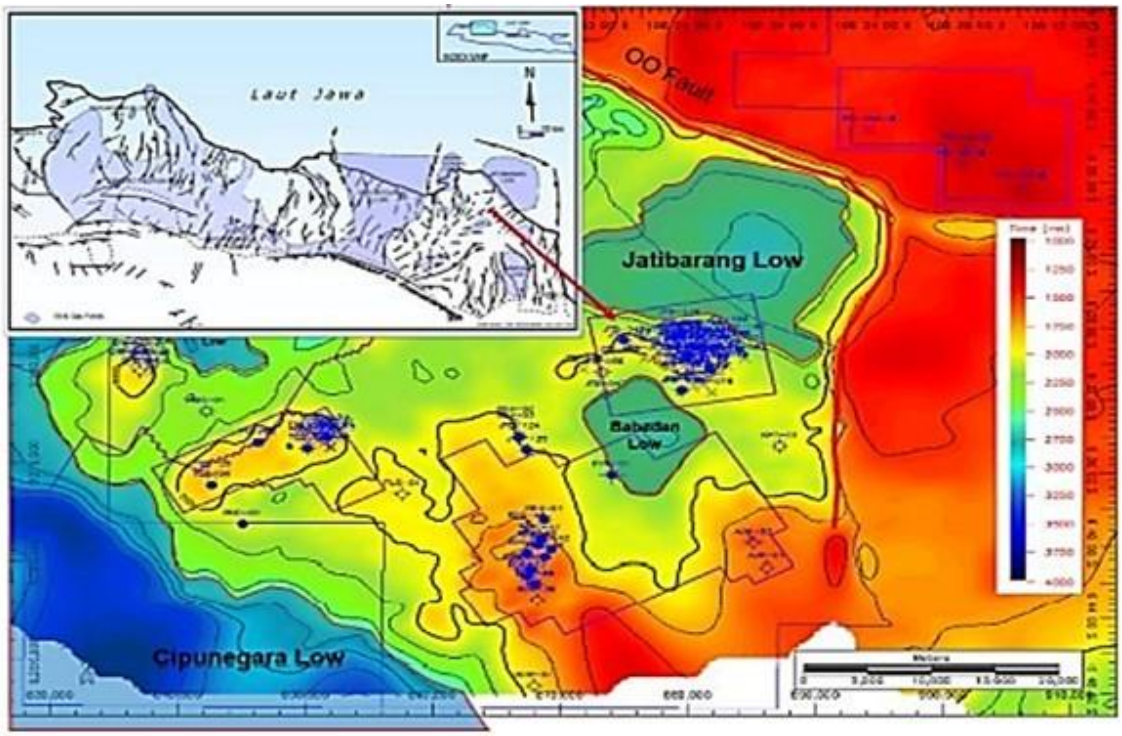

Figure 3. Regional Time Structure of Jatibarang Volcanic, situated at Jatibarang Sub Basin (Pertamina, 2015)

Volcanic Jatibarang was also found in several wells in the eastern northwest Java basin area (Sindang, Akasia Maju, Randegan, Jati Asri, Tegal Taman). However, this region has not yet been developed. Typically high to overscale resistivity, low matrix porosity, and secondary porosity existed in this region. Indicating fractured lithology by cementation factor and image log (FMI) was suggested. The boundary between volcanic and limestone is not yet detected by regional seismic. In the offshore area, volcanic Jatibarang was also penetrated by Pertamina Hulu Energi (PHE) Offshore North West Java (ONWJ), which suggested that three-phase eruption predicted occurred from Paleocene to Late Oligocene (Figure 4).

Volcanic Jatibarang lithology consists of lava, breccia, and a variety of tufa interpreted as a rework of volcanogenic because a mixture of various lithic fragments is found. Since 1970, volcanic Jatibarang has faced disputed concepts about facies and porosity.

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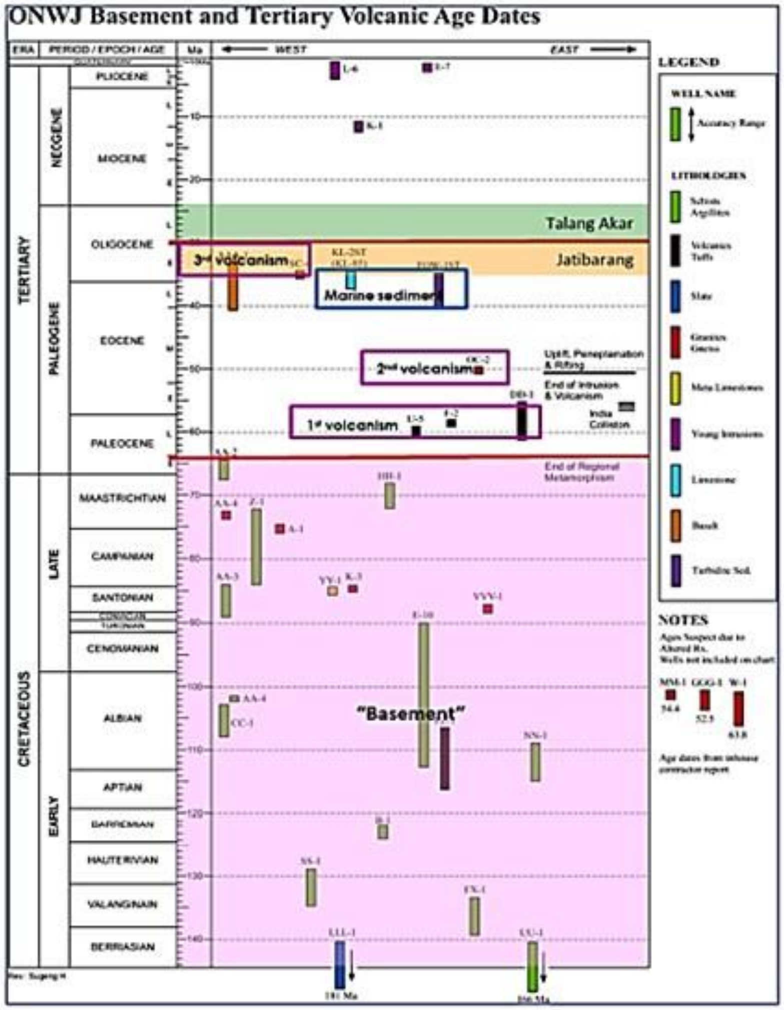

Figure 4. Volcanism during Paleocene to Oligocene by dating of offshore area (SKK Migas, 2019)

Materials and Methods

A conventional geology concept was applied to generate a geology model of the area. A whole of the volcanic body was accounted for reservoir without considering its facies and porosity heterogeneity. Production performance of volcanic Jatibarang was unique: high performance in the early years, then steeply depleted in the next 3 years later and flatted over 20 years. The vertical curve indicates depletion of fracture support, followed by flat production.

The production forecast (Qoi) of volcanic Jatibarang was 500-400 BOPD. This was an excellent initial production reference to other northwest Java basin wells. The initial production contradicted thin permeability from SCAL data (less than 0.1 mD). Well test by PBU indicates hundreds to thousands of milliDarcy permeability, which is unusual for matrix-supporting porosity in the northwest Java basin. Boundaries are infinitive, and reservoir engineers interpreted even a homogenous reservoir model as fracture porosity (Figure 5). According to the newly developed facies concept, the explosive one was hydrocarbon by the dual-porosity reservoir. The dual porosity system in the volcanic Jatibarang reservoir was supported by a drilling well history, 46 wells, and 400 lpm to total loss circulation. This data contradicts thin permeability from SCAL data (less than 0.1 mD).

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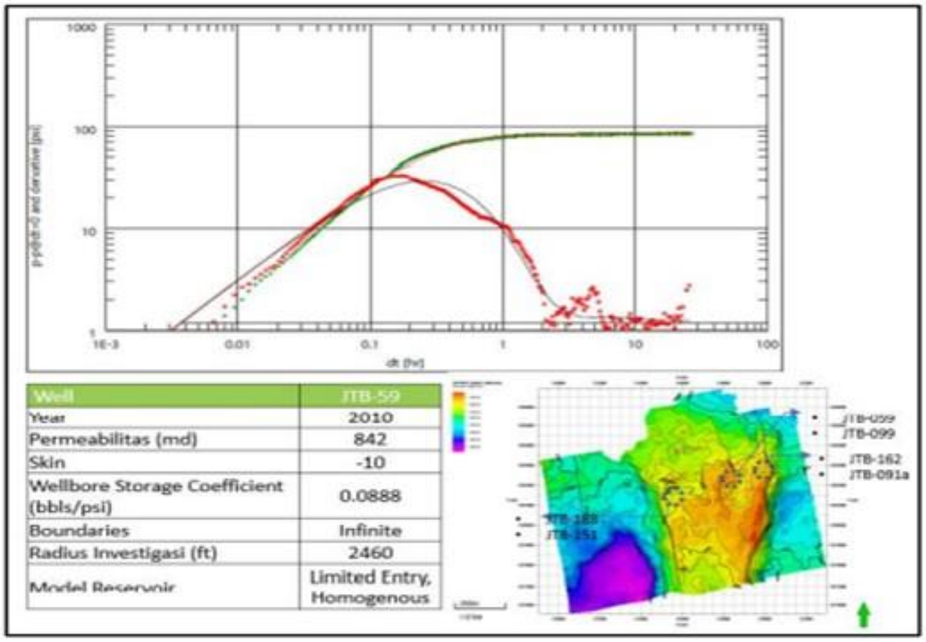

Figure 5. Well test of JTB-59 indicates fracture porosity supporting the open-hole production

Referenced to any evidence, in 2014, Pertamina EP developed a new concept about facies and property heterogeneity by a new formation evaluation method by 69 well logs, 15 sonic logs, two production logs, eight well cores, 2 XRDs, 3 FMIs, and 39 well tests. The new concept reservoir (Figure 6) has redefined and improved the original oil-in-place (OOIP) calculation from 551.032 MSTB to 585.794 MSTB.

Results

Volcanic Jatibarang and another Eocene reservoir in the northwest Java basin area had faced low accuracy data from core description analysis. Petrophycisist should work more carefully in calibrating the log and its supporting data.

The volcanic Jatibarang reservoir was characterized by volcanic rocks resulting from direct volcanic activities (primary) and indirect volcanic activities (secondary). Direct volcanic activity is the process of magma rising towards the surface (eruption) in the form of explosive and effusive or another related process. Indirect activity (secondary) is the process that follows the primary activity. Rock formation/volcanic deposits are a product of primary or secondary volcanic activities in a time interval; explosive and effusive mechanisms produced volcanic Jatibarang according to 8 wells of core data.

Six facies were identified from the type of log and electro-facies parameter. The lithology of volcanic Jatibarang consists of lava, breccia, and a variety of tuff interpreted as a rework of volcanogenic because there is a mixture of various lithic fragments. Bogie and McKenzie's concept has been correlated with geometry distribution for reservoir modeling.

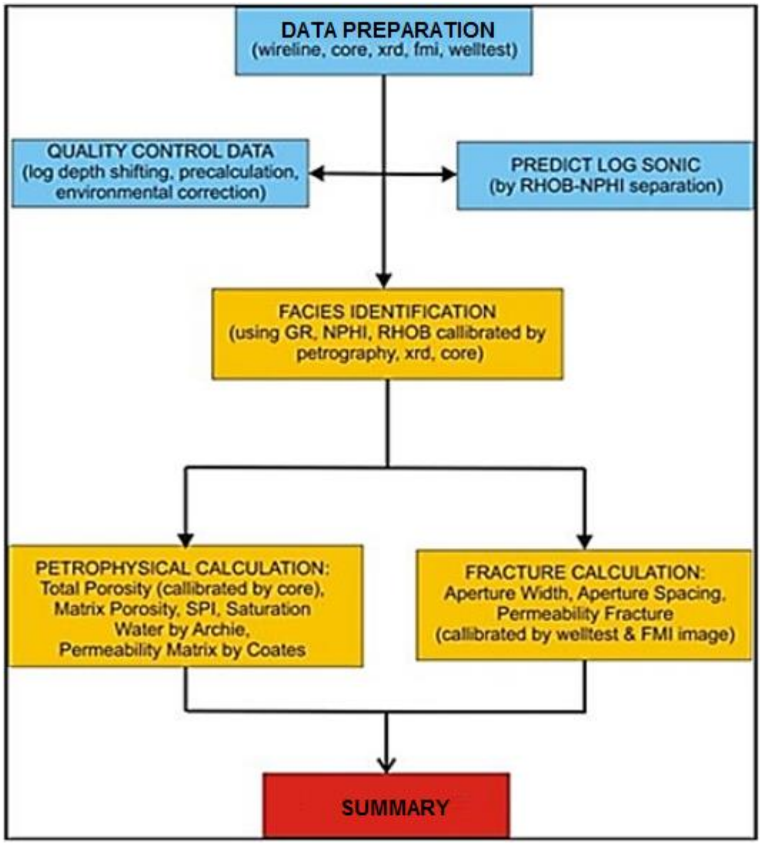

Figure 6. Reservoir characterization workflow for volcanic Jatibarang

Volcanic Jatibarang is a 'clean facies' with minor clay minerals, but their matrix could not act as an excellent, effective porosity. According to XRD from JTB-52 (Table 1) and JTB-63 (Table 2), chlorite will cause any matrix porosity to plug along the rock particle.

Table 1. Mineral composition of the volcanic Jatibarang from JTB-52

Depth (m)	Qz	Felspar	Kaolinite	Chlorite	Calcite	Organic & amorphous
2180.87	25	45	3	15	-	10
2182.58	25	30	15	15	10	5
2184.65	10	55	<5	15	10	5
2180.58	<5	65	<5	15	5	5
2187.53	10	50	<5	10	20	5

Volcanic Jatibarang was typically suggested as a high gamma-ray reservoir due to its relatively rich K-feldspar content, based on XRD JTB63 and JTB-52 (Table 1). Crossover density-neutron demonstrates at non-low gamma-ray, which defined this volcanic Jatibarang as explosive facies, sedimented by pyroclastic, and deposited as tuff. According to JTB-113, there are two types of the tuff reservoir: a) tuff with aphanitic texture, glass mass, and cement infilling microfracture as a vitric tuff, and b) non-glassy crystalized tuff. Density-neutron shading with different patterns was consistently found in all wells that penetrated volcanic Jatibarang. According to the petrography of JTB-113 (Figure 7), vitric tuff is mainly composed of the aphanitic groundmass. Some porosities are found along with fractures (opening), and some are infilled by chlorite and quartz (closed fractures). Density-neutron shading with different patterns is consistently found in all well penetrated on this volcanic Jatibarang. Fractures connect, defined as partial and conductive fractures (refer to FMI JTB-120), as shown in Figure 8. This

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suggests a cooling effect of pyroclastic sedimentation from high-temperature lava flow products. FMI is formation micro-imager. FMI log is commonly used for facies classification and description. This FMI is also can be used for interpreting fractures. Vitric tuff is typically 'gassy reservoir' neutron density crossover with overscale resistivity and low sonic porosity. The non-glassy crystal tuff is a typical 'oil reservoir' with a neutron-density crossover with flat low resistivity and high sonic porosity. Both lithic tuff and breccia are zero effective porosity.

Table 2. Mineral composition of the volcanic Jatibarang from JTB-63

Depth (m)	Qz	Felspar	Kaolinite	Chlorite	Calcite	Organic & amorphous
2024.14 – 2024.44	35	35	20	-	-	10
2025.17 – 2025.48	40	35	15	-	-	10
2026.80 – 2027.01	40	40	15	-	-	5
2027.68 – 2027.93	45	25	15	-	-	10
2025.18 – 2028.38	40	35	5	10	-	5

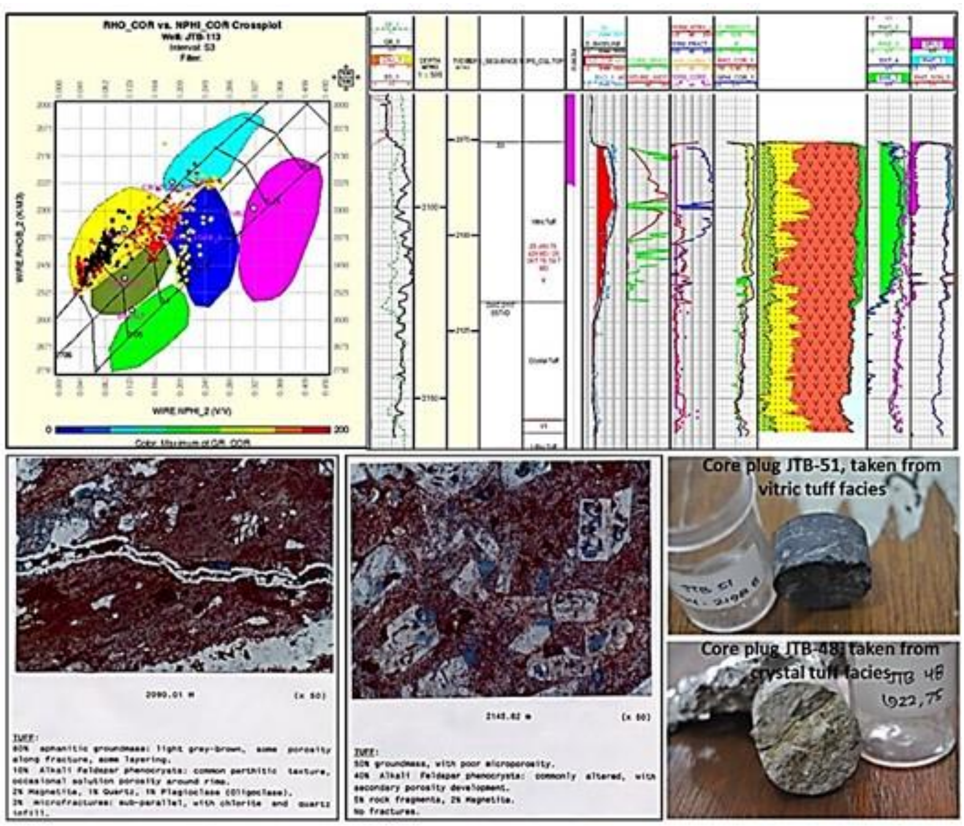

Figure 7. Rock typing for volcanic facies from triple combo, petrography, and core plug JTB-113, JTB-51, JTB-48

No detected fracture is developed by deep resistivity and sonic. The effusive lava is characterized by a low gamma-ray, look-like reservoir but does not contain any hydrocarbon. The image log shows the width of the aperture of the fracture (refer to FMI JTB-120), but the connectivity, in this case, has not been indicated by the triple combo. The ability of fracture as a hydrocarbon conduit remains a big question until now. According to FMI JTB-120, partial and conductive rupture is found in lava. This study has generated two classes of lava: porous and tight lava, which are different from rock typing.

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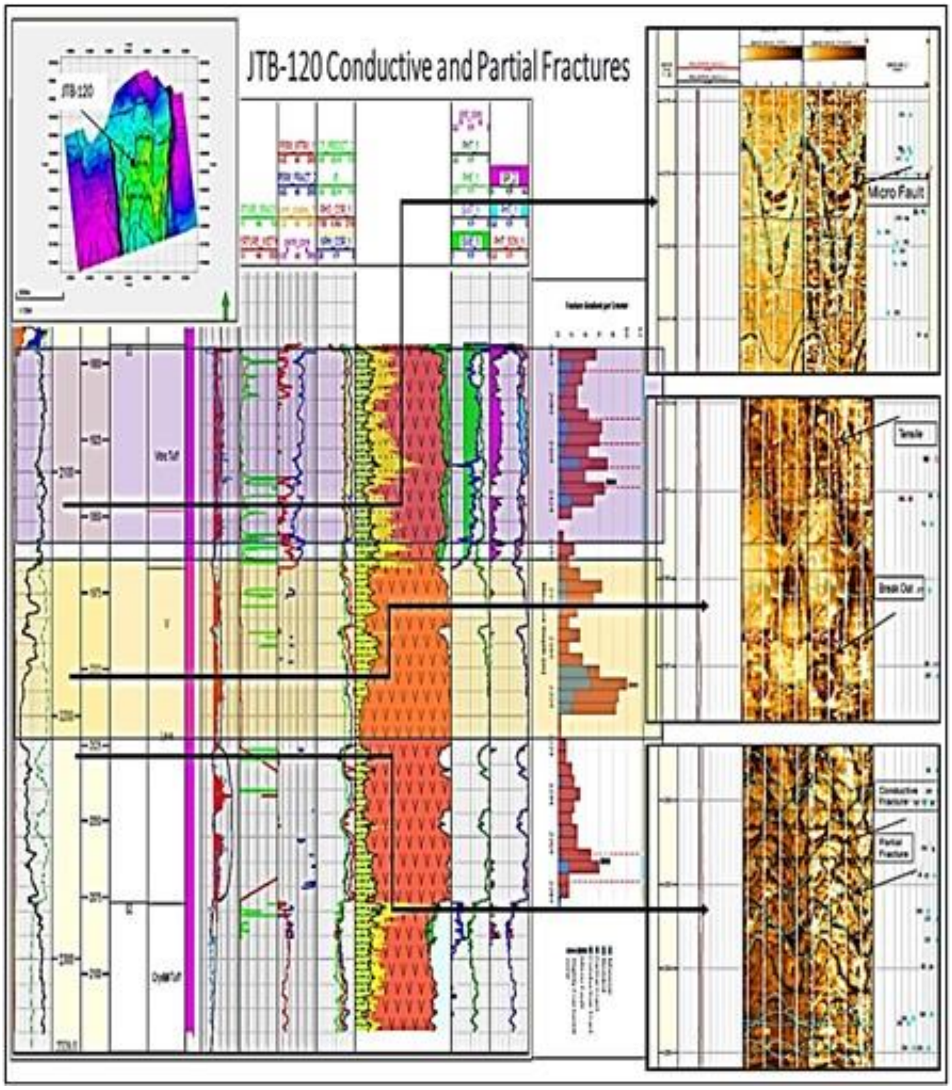

Figure 8. Fracture identification by FMI of JTB-120

Discussion

Each volcanic facies has its own electrofacies parameter (Bronto, 2006; Zou, 2013; Benyamin & Salsabila, 2020). Gamma-ray, density-neutron, deep resistivity, and sonic can be used for 'volcanic rock typing.' According to fractional flow from the unique analysis core (which has been validated by performance production), a 10 Ohm meter is the resistivity cut-off for a fractured reservoir in any volcanic facies. Further discussion is needed to obtain both matrix and fracture supported in lava as a hydrocarbon reservoir.

A deep resistivity pattern is a quick hypothesis of fracture existence in the rock. Height deep resistivity log could affect tight formation in some lithologies. In volcanic, the deep resistivity is typically high and spiky. Some cases tend to overscale, representing hydrocarbon infilling fracture (refer to JTB-113). Spiky laterolog deep (LLD) in JTB-113 has proven as fractured lithology from the well core data, with well core cumulative 3 MMBBL liquid, from which 1 MMBBL oil is from volcanic Jatibarang. LLD was used by Tarek & Elhamy (2013), Sibbit & Faivre (1985), and Vastari (2011) in their studies.

Fractures' existence is reflected by overscale deep resistivity pattern in a spiky way with sonic log overrunning density log. Deep resistivity was the primary indicator of fracture. Some fracture reservoir studies were Louis (1980), Khalil *et al.* (1993), Creties *et al.* (2009), Tae & David (2009), Vasvari (2011), Jun *et al.* (2009), Huy *et al.* (2012), Marie *et al.* (2012), Peter *et al.* (2012), Suardana *et al.* (2013), and Tarek *et al.* (2013). The spiky pattern is

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the best method to calculate the width of the fracture aperture; unfortunately, no fracture is calculated in the FMI analysis of Jatibarang.

Regionally, deep resistivity was used to calculate the width of the opening in fracture-supported porosity. Data from JTB-120 was used for this case. The fracture analysis using FMI data for JTB-120 was completed and calibrated with a triple combo log. The analysis suggested a dual-porosity system and 1 MMBBL cumulative oil in non-fracture porosity well.

In the case of volcanic Jatibarang, evaluating a fractured reservoir requires a particular porosity calculation, i.e., Nelson Equation (Nelson, 2001). Aperture width, spacing, and permeability fracture variables are used in the Nelson Equation with some modifications. In the volcanic Jatibarang, the permeability core cannot be used because of the unpreserved core barrel due to the delicate texture of the tuff. Permeability fractures generated from Nelson's method line with cumulative oil production are presented in Figure 9. With only 2-5 % porosity, the fracture system could support hundreds to thousands of mD and contribute millions of barrels of oil over 20 years. New drilled well of volcanic Jatibarang, JTB-211, spud on September 17th, 2016. A Qoi gross/net/WC: 387 BLPD/336.69 BOPD/13% from vitric tuff facies is suggested as cased hole completion with swellable packer from non-reservoir (Figure 10).

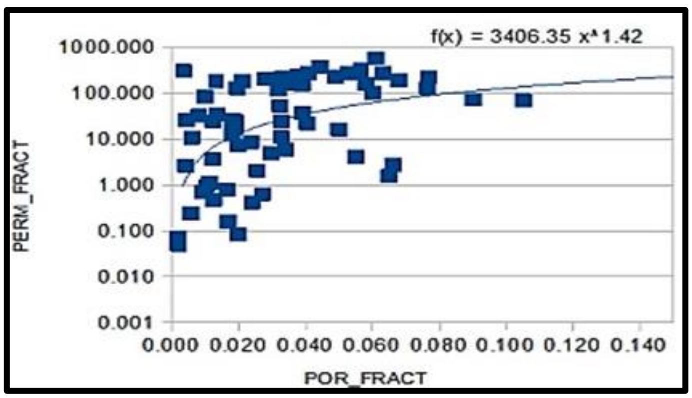

Figure 9. Fracture porosity and permeability relationship

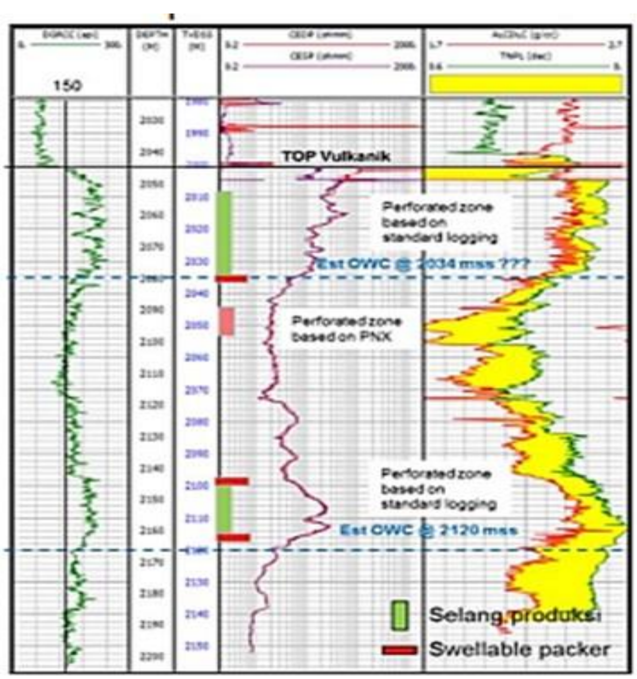

Figure 10. JTB-211 type log, swellable packer

In March 2017, the water cut increased, gross/net/WC: 240 BLPD/88 BOPD/63%. Advanced logging, Pulsar multifunction spectroscopy (PNX) was running to measure another interval from volcanic Jatibarang with oil saturation. Crystal tuff was interpreted as non-reservoir based on a triple combo—this facies belief as oil zone due to high CO ratio based on PNX log. An increasing water cut occurred on August 25th, 2017, gross/net/WC: 481 BLPD/4.8 BOPD/90%. PNX log has not shown accurate saturation. Nevertheless, the conventional property models were the best characterization and fracture calculation method in the volcanic Jatibarang.

Conclusion

Volcanic Jatibarang lithology consists of lava, breccia, and a variety of tufa interpreted as a rework of volcanogenic because of a mixture of various lithic fragments. A new concept of formation evaluation attempts to distinguish the fractured vitric tuff reservoir and non-reservoir zone, both effusive lava and explosive product. Reservoirs differ from common clastic-carbonate, typically high gamma-ray reservoirs due to potassium feldspar composition. A sonic overrunning density log aligned with a deep resistivity pattern reflects fractures' existence. Calculating the measured width of apertures, spacing intensities, and fracture permeability comprehensively describes reservoir performance.

Acknowledgment

The authors would like to thank the Universitas Trisakti for technical support and Pertamina Hulu Energi for their consent to release the data for this publication.

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