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Determining the Lithology Type of Volcanic Rocks Using Logs and Cores

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ABSTRACT : There is still very little research on hydrocarbon reservoirs in volcanic rocks in the world due to the limited discovery of hydrocarbons in these reservoirs. The existing logs are currently made only for interpretation in sandstone and carbonate rock reservoirs so that if the existing logs are used for analysis on volcanic rocks, they will give a different response when compared to the response on sandstone and carbonate rocks. This research aims to develop a method for characterizing lithology and productive zones in volcanic rocks in the X Field research area which includes identifying volcanic rock types, determining property values consisting of porosity, saturation exponent (n), cementation (m), formation factor (F) and tortuosity (a) as well as other petrophysical parameters. The data used includes log data recorded from 150 X Field wells including electrical, nuclear and sonic logs as well as fracture identification logs. One third of the data is processed and analyzed to obtain quantities and equations used for lithology identification and characterization of productive zones in volcanic rocks, The results of this application were then validated with core data
From this research, it can be seen that the log can identify X volcanic rocks into 3, namely: epiclastic sandstone, pyroclastic which consists of; Tuff, Tuff breccia and Lava consisting of Andesite

KEYWORDS – Epiclastic, Lava, Lithology, Tuff, Volcanic Rocks

I. INTRODUCTION

Hydrocarbons in the world are generally trapped in clastic and carbonate reservoirs. Only very few hydrocarbons are trapped apart from these two types of rock, one of which is volcanic rock reservoirs. Not many countries in the world have volcanic rock reservoirs. Indonesia is one of the few countries that has hydrocarbon reservoirs in volcanic rocks. Apart from the limited number of volcanic reservoirs in the world as mentioned above, volcanic rocks also have their own uniqueness in the analysis of readings of the response of geophysical well logs, hereinafter simply called logs which until now for commercial purposes have been made based on calibration of basic limestone and sandstone data. has been done a lot, while studies on volcanic rock reservoirs themselves are still very limited. Khatchikian and P. Lesta (1973) conducted research on mixed volcaniclastic rocks from sandstone and volcanic rocks (hybrid) in Argentina, which are basically sedimentary rocks and not pure pyroclastic rocks. E.L Sacco (1978) also carried out the same research on volcaniclastic rocks and was still limited to determining rock types and had not carried out analyzes related to the existing fluid content. A.Khatchikan (1982) characterized volcanic rocks using the M-N method and MID method which is a response to neutron logs, density and sonic and began to introduce saturation calculations in these rocks although still using calculation methods usually carried out on clastic rocks as hydrocarbon reservoir rocks. which are often found in the world. Currently intensive research is being carried out on the hydrocarbon potential in basement fracture reservoirs in the Cuu Long Basin research area in Vietnam with different types of basement rock different from volcanic rocks. Reports on the results of this research, including the type and magnitude of porosity in the reservoir, as well as a comparison between the magnitude of porosity resulting from the log response compared to the porosity resulting from core rock, were only presented at the internal technical forum (Technical Forum-Cuu Long Basin Exploration) and not published

By carrying out this research, it is hoped that a special log response analysis method will be obtained for the lithological characterization of volcanic rocks which includes identifying types, determining petrophysical parameters and productive zones comprehensively and will be able to be used on similar volcanic rocks in other places, not limited to the X area as a research location.

II. LITERATUR REVIEW

Reservoir characterization is needed to be able to know the type of lithology that makes up the reservoir, the distribution of the reservoir vertically and laterally, to know the petrophysical quantities of each reservoir such as resistivity, porosity and other petrophysical quantities for saturation calculations which can ultimately be used to calculate the reservoir reserves. quite economical for geophysical exploration activities or hydrocarbon exploitation. Hydrocarbon reservoirs that are often found in the world generally consist of two types, namely clastic (sandstone) and carbonate (limestone). For other reservoirs, such as volcanic rocks, it is still very rare to find them and if there is an attempt to find out where in the reservoir the productive zone is located and how it is distributed, it is not easy.

Volcanic Rock : Volcanic rocks (hereinafter referred to as pyroclastic rocks) are produced by volcanic explosions. Pyroclastic rock is a type of fragmental igneous rock that is widely discussed by geologists and has an important role in the geological reconstruction of an area. Pyroclastic fragments are produced by volcanic explosions and ejected from the crater of the volcano . The term primary is used for material that has not moved from its place of deposition before the lithification process. Meanwhile, reworked pyroclastic material that moves before the lithification process due to the influence of gravity or other landslide processes cannot be categorized as an epiclastic process. Thus, it is very possible for primary porosity to form in both primary and reworked pyroclastic rocks. The epiclastic process is defined as the process of sediment formation through the weathering and erosion stages of lithified rocks (Fisher, 1961). Fisher's classification can be seen in Figure 1

Mc, Donald (1972), stated that pyroclastic material is fragmental, can be liquid or solid when ejected by a volcanic explosion and after it becomes a solid mass it is called pyroclastic rock. The term pyroclastic material can be replaced with tepra as stated again by Thorarinsson (1951), which was actually used long ago by Aristotle but was later forgotten by people. Volcanic explosions can occur on land or under the sea. Heinrich (1956) defined pyroclastic rocks as rocks composed of detrital material ejected from volcanic craters, transported through the air and deposited on the surface of land, lakes or sea water. Apart from that, there is also material that is transported as nues ardantes, which is solid and in the form of glowing avalanches. Jackson (1970) stated that pyroclastic rocks are composed of fragmental material erupted from volcanoes and mainly accumulated as solid material. Pyroclastic material can fall into sedimentation basins or be transported by rivers into sedimentation basins so that it is very likely that gradations will form between pyroclastics and sediment.Pettijohn (1975), explained the term pyroclastic as a characteristic used for rocks formed by material resulting from volcanic explosions. These materials can be accumulated on land or below sea level. Pyroclastic material can be included in the group of volcaniclastic materials in addition to material resulting from weathering and erosion of older volcanic rocks.

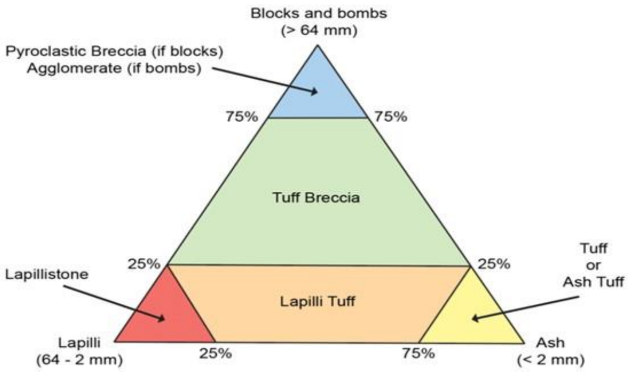

Figure 1: Ternary diagram of grain size terms for the classification of pyroclastic rocks and fragmental volcanic rocks,modified from Fisher and Schmincke 1984 (Pavel.H et.al,2019)

Geophysical Well Logs : A wellbore geophysical log (log) is a tool that is lowered into a drilled well using geophysical methods to interpret rock properties qualitatively and quantitatively. This tool was first made by the Schlumberger family from France in 1930. The basic principle of logs is to measure physical parameters at each depth precisely and continuously from the rock formation that has been penetrated by drilling. Based on the physical properties measured, logs can be divided into 3, namely; Electrical logs (resistivity), Radioactive logs (gamma, neutrons) and sonic/acoustic logs

Electrical logs : The electric log is the oldest recording tool used in industry. The principle is that electrode A is charged by a generator so that between A and B there is a potential field. The current used is AC (alternating). The electrical strength at each location is influenced by the resistivity of the surrounding formation which is measured by the M and N electrodes which record it automatically. By slowly pulling the two electrodes A and W from the bottom of the well upwards, various layers with different resistivities can be recorded.

Radioactive logs : The Radioactive Log measures the radioactivity properties of the formation, namely; natural radioactivity or gamma rays and radioactivity caused by a neutron source fired into the formation. Gamma ray logs measure the gamma rays emitted by rocks. This light is received by an ionization tube and the received pulse is amplified and then recorded on the surface. The radioactivity measured depends on the type and relative strength of the gamma rays emitted from each rock. Gamma rays fluctuate up and down, so what is taken is the average value. In the neutron log the resulting curve depends on the amount of hydrogen contained in the formation being measured which comes from water or hydrocarbons. A radioactive source emits neutron particles rapidly. If there are no hydrogen atoms, neutrons will be captured by CaCO3 in limestone or Si02 in sandstone into their atoms, which makes them unstable. To ensure stability, secondary photon gamma rays are emitted which are captured by the ionization tube which are then amplified and recorded on the surface. If hydrogen is present, these high-speed neutrons are slowed down by hydrogen ions so that there will be little or no secondary gamma rays. The measurement of gamma-gamma logs or in the industry known as density logs is based on a gamma source (usually Co60) which is placed on a rod that is slid along the well skid. These gamma rays interact with electrons in the surrounding material and are then reflected back to be received by the detector. The intensity of the reflected light depends on the density of the surrounding medium or rock and the filling fluid within it (bulk density). The deflection or intensity received by the detector is directly recorded as bulk density which is directly proportional to porosity.

Sonic/Acoustic logs : The third basic type of log is a sonic log or also called an acoustic log. The principle of this log is to measure the speed of propagation of elastic waves in rocks so it is also called an acoustic log. A strict magneto oscillator is used as a transducer to convert electrical energy into vibrational energy, so that it functions as a transmitter for elastic wave pulses in the form of a series of short-term waves with constant amplitude and frequency. The series of waves emitted is such that it is a function of the height of the transmitter. The three logs are put together in one layout which is called Triple Combo (Figure 2)

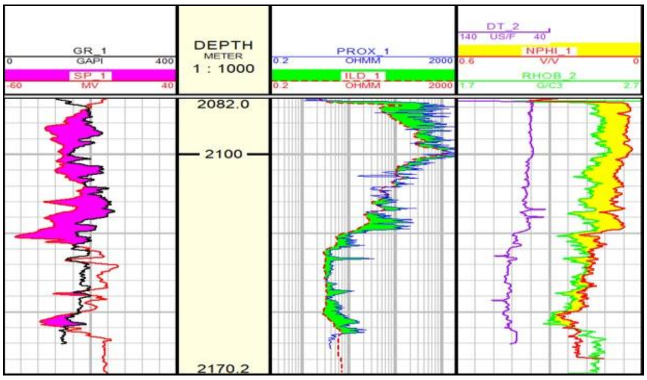

Figure 2: Triple Combo Log

III. MATERIAL AND METHOD

This research was carried out with the main data in the form of log recording results. The types of logs used in this research and the principles of how they work have been described in the previous chapter. The data used in this research was taken from 150 wells in the X Field (Indonesia). Apart from log data consisting of standard resistivity and porosity logs as well as additional logs for fracture analysis, core rock data is also used which is analyzed macroscopically and microscopically, SEM and XRD analysis**.**

Physical Log Modeling : After quality control in the form of calibration and correction is deemed adequate, the next stage is to carry out physical log modeling. Physical log modeling is made based on log data selected from the X field and its surroundings which has been validated with core rock data taken from the same interval so that the log data taken for physical modeling truly represents each type of reservoir rock in the X formation. . The physical modeling of this log consists of two parts, namely making a sandstone rock model which will be used as a reference model and making a volcanic rock model which will be characterized by its lithological type

Sandstone Models : The creation of a physical model of sandstone logs as a reference model is made from the results of physical quantity measurements of core rock data in the laboratory, the procedure of which is explained at the bottom of this chapter and selected resistivity log measurement data which is also based on the consideration of the large number of studies that have been carried out on sandstones both for research purposes and industry, especially the oil industry, so the quantity values used are both log quantities and parameters that will be used for saturation calculations as a method of qualitative hydrocarbon characterization more valid.

The choice of sandstone as a reference model is related to the use of the Archie equation which, if necessary, will later be used as an equation to calculate saturation where the model used in research conducted by Archie uses a sandstone model, so the use of sandstone as a reference model is expected to be in line and in accordance with the objectives of this research. The sandstone model has a gamma ray value of 14-19 API SP –60 to –50 mv, Ild 3-20 ohm-m, Msfl 2-13 ohm-m, Rho 2.18-2.22 gr/cc, Nphi 13-18 pu, porosity 25-30 %, dtP 128-134 us/ft, dtS 75-78 us/ft, Pef 2.3-2.5 barn, Ro 1.6-1.7 ohmm.

IV. RESULT AND DISCUSSION

In this chapter, the research results of all rock models in Field X which have volcanic reservoirs are presented which were taken from log data and core rock data as validation. All rock types in the reservoir, including reservoirs containing hydrocarbons and dry ones, are determined based on petrographic analysis using Fisher's (1966) classification.Based on petrographic analysis using this classification, it can be determined that the Volcanic Reservoir consists of 3 types of lithology, namely: Clastic, Pyroclastic and Lava. Meanwhile, other rocks that are also found in the volcanic reservoir are a mixture of the three types above.

Clastic : The clastic rocks found in the Reservoir Volcanic consist of two lithologies, namely Epiclastic Sandstone and Claystone. For claystone, the author does not discuss it because the clastic rock used as a reference reservoir rock model is sandstone. This Epiclastic sandstone, as explained in the previous chapter, is used as a reference model, has a description as a clastic sedimentary rock, grayish white in color, fine - medium sand grain size, well sorted, closed packing, good porosity, composed of quartz minerals (dominates). and feldspar and a few mafic minerals, the matrix is relatively absent, with silica cement referred to as quartz sandstone. The results of the petrographic analysis of this sandstone have a grain size ranging from 0.15-0.71 mm (with an average of 0.31 mm). The grain shape is generally at an angle, well sorted, the grains generally contact planarly and are concave-convex. The composition is composed of mono-crystalline quartz grains (>50%), rock fragments (16%), feldspar (0.75%), mica (2%), heavy minerals and carbon minerals (a little), having a visual porosity above 10%. These clastic rocks were then used as a reference model

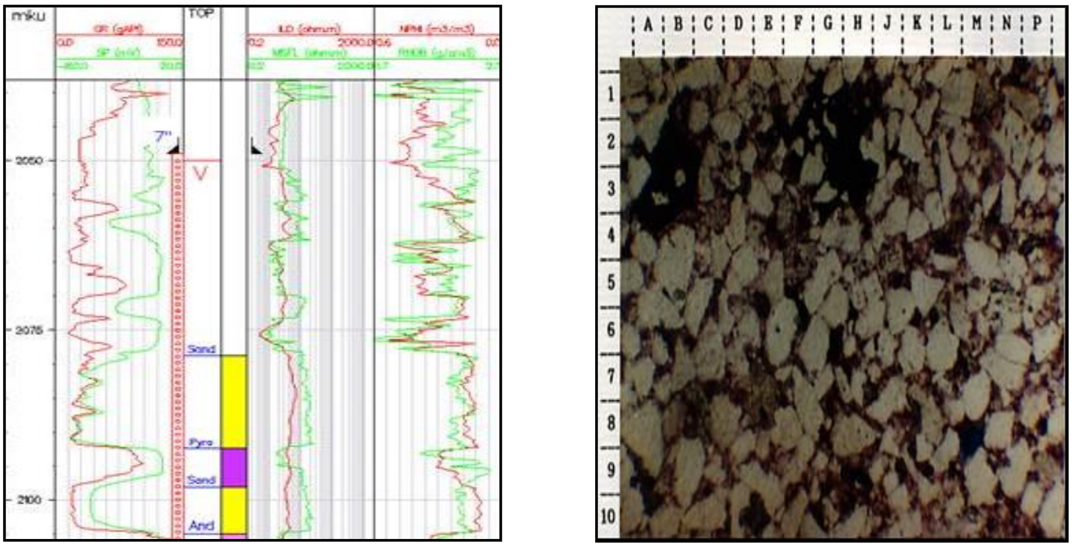

Figure 3 : Log (a) yellow color and petrographic section of Quartz Sandstone
with excellent porosity appearance (b)

4.2 Piroklastik

Volcanic reservoir pyroclastic rocks consist of Tuff and Agglomerate

Tuff : The tuff is grey, clastic, brownish grey, very fine grained, fractured, compact, composed of a very fine glass matrix, sometimes visible in the presence of plagioclase minerals and a little pyroxene and biotite, and some of it has been converted into silica and clay minerals. Microscopic identification of this rock sample shows that the grain size is very fine, ranging from 0.02-0.12 mm with an average grain size of 0.025 mm. The rock samples have experienced very intensive alteration, where almost all of the constituent components that can still be observed consist of feldspar (18%), a little mafic (0.5%), quartz (6.5%) and a base mass of glass (>60%) which is almost all of them have been altered to become authentic clay and secondary silica. Mineral alteration products include authentic clay minerals, silica, chlorite, ore minerals and iron oxide. The tuff found in the volcanic reservoir based on log response analysis can be divided into three, but based on the petrographic analysis as explained above, it can be seen that in fact the rock genesis is one type, the log response gives three different characters caused by different fracture intensities in the tuff. the. As a result, the intensity of the fractures in the Tuff reservoir is not the same, this causes the magnitude of the fracture porosity and also the amount of fluid contained in the rock to be different and result in the response given by the log being different too. When compared with the reference model, the Volcanic Tuff reservoir has different values of log physical quantities compared to the reference model.

Almost all log physical quantities have quite significant differences, especially the difference in log quantities

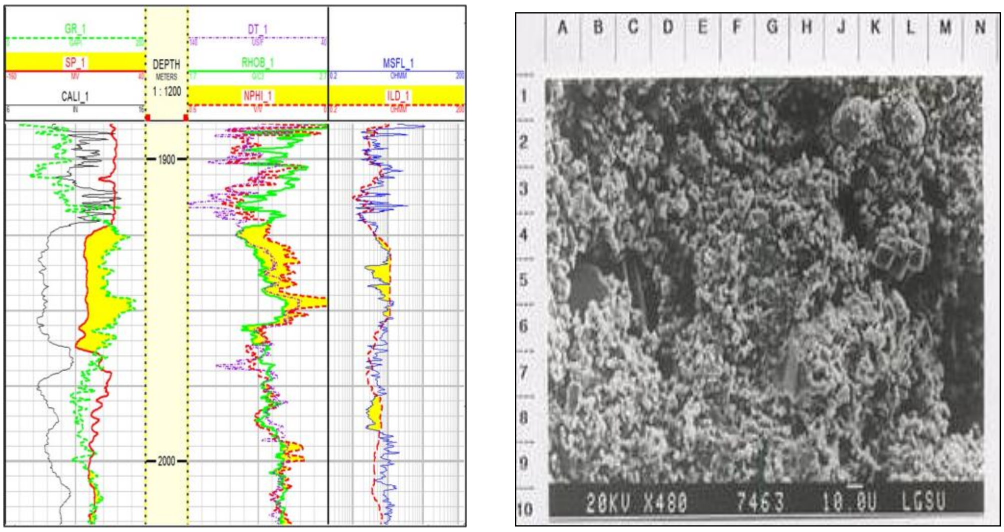

Figure 4 : Log (a) and petrographic section of Tuff with fracture porosity appearance (b)

Tuff Breccia : Pyroclastic rock, greenish gray, clastic, grain size 0.5-1 mm, composed of rock fragments and plagioclase minerals and a little pyroxene and biotite, as well as a very fine volcanic glass matrix, some of which has been converted into silica chlorite and clay minerals , open packed, medium sorted (Figure 5) Based on microscopic identification, this pyroclastic rock has a grain size ranging from 0.1 – 1.45 mm, but some grains reach a size of 5 mm. The intensive alteration means that examples of this type of rock from core data taken show that some of its components have changed into secondary minerals. The rock composition is composed of an association of rock fragments (> 35%) and basic glass mass followed by a small amount of plagioclase crystals (6.5%), ore minerals (2.5%) and mafic minerals (1%). Secondary mineral alteration products that can be identified include authigenic clay, silica, chlorite, calcite and zeolite. When compared with the reference model, the Jatibarang Volcanic Agglomerate reservoir has different values of log physical quantities compared to the reference model. There is no significant difference in the physical magnitude of the Lithic Tuff log compared to the reference model. This difference, as in other non-sandstone volcanic reservoirs, is probably caused by the composition of the minerals and the mechanism of formation of agglomerate rocks which are different from sandstone.

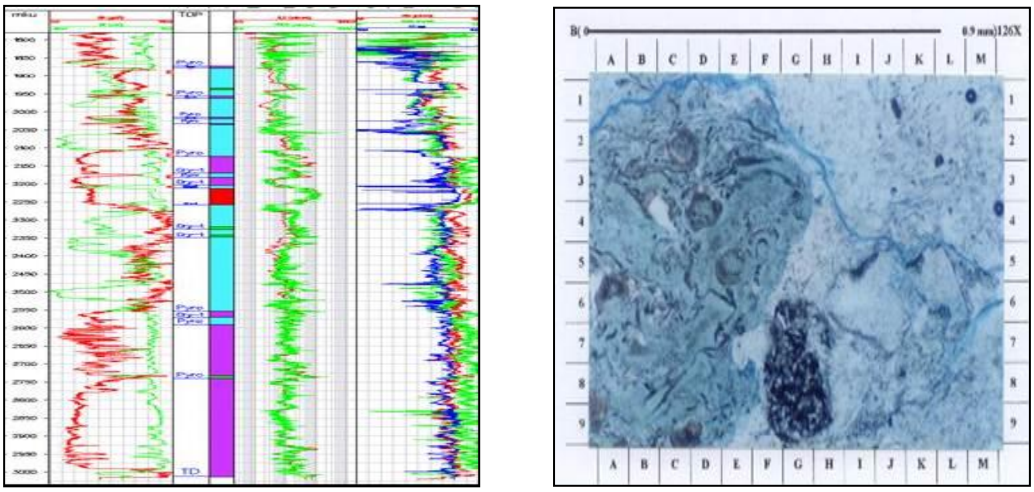

Figure 5 : Log (a) and petrographic section of Tuff Breccia (purple) with no porosity appearance (b)

Lava : Intermediate igneous rock, gray in color, hypocrystalline, slightly porphyritic, composed of plagioclase phenocrysts and mafic minerals (pyroxene), and aphanitic base mass ,some glass (Figure 6). Rocks have generally been changed to clay minerals and a little silica. Thin section analysis of the outer igneous rock shows a pilotaxitic hypocrystalline texture. The crystal size ranges from 0.07 – 0.45 mm, relatively uniform, but there are some crystals that are quite large as phenocrysts. The crystal form is generally unhedral-subhedral, with the twins still being observed in the form of calcbad twins, but almost all of the crystals have been damaged by quite intensive alteration, and some of the constituent components have undergone transformation into secondary minerals. The main constituent of this rock is plagioclase (Phenocrysts, 7% and Microliths, 54%) associated with a small amount of mafic minerals (10%), glass mass (5%) and ore minerals. When compared with the reference model, the Volcanic Andesite reservoir does not have a significant difference to the reference model, this difference in magnitude, as is the case in other non-sandstone volcanic reservoirs, is probably caused by the composition of the constituent minerals and the mechanism of formation of andesite rock which is different from sandstone

V. CONCLUSION

1. Logs and petrological analysis (megascopic and microscopic) can identify the type of lithology of the reservoir volcanic rock reservoir into 3 types, namely Epiclastic Sandstone, Pyroclastic consisting of Tuff and Tuff Breccia and Lava which consists of Andesite. All of these lithologies have experienced polyphase fracturing, the type and intensity of these fractures is what causes differences in the log response

2. Epiclastic sandstone has a log response and petrophysical quantities that are close to the response of the sandstone used as a reference model, so no correction is needed to identify the rock.

3. The research results show that Fractured Tuff Types , Lava Andesite have log responses that are very different from the ideal model, namely GR – 15 to 277 API, Resistivity – 17 to 2660 ohm-m, Density 0-0.56 Gr/cc, the research results also show that Fractured Tuff Types and Lava Andesite have log responses that are very different from the ideal model, namely GR – 15 to 277 API, Resistivity – 17 to 2660 ohm-m, Density 0-0.56 Gr/cc, meanwhile in Tuff Breccia lithology there is no significant difference in response to the ideal model

4. All identifications of volcanic rock lithology types have been validated with core rock data which makes the results of this research accurate

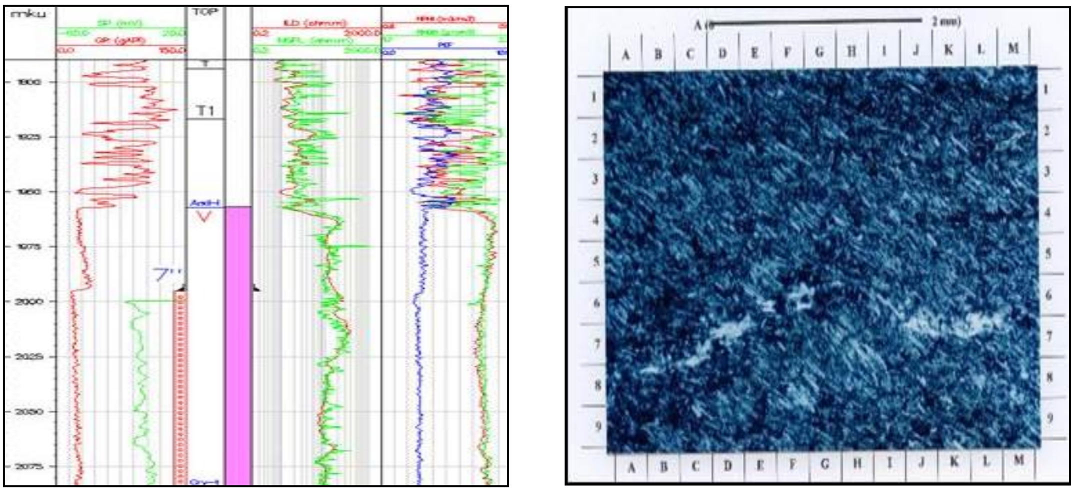

Figure 6 : Log (a) and petrographic section of Lava (pink) with no porosity appearance (b)

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