Hydrocarbon Reservoir Identification in Volcanic Zone by using Magnetotelluric and Geochemistry Information

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Abstract. The resistivity of Magnetotelluric (MT) data show the resistivity mapping in the volcanic reservoir zone and the geochemistry information for confirm the reservoir and source rock formation. In this research, we used 132 data points divided with two line at exploration area. We used several steps to make the resistivity mapping. There are time series correction, crosspower correction, then inversion of Magnetotelluric (MT) data. Line-2 and line-3 show anomaly geological condition with Gabon fault. The geology structure from the resistivity mapping show the fault and the geological formation with the geological rock data mapping distribution. The geochemistry information show the maturity of source rock formation. According to core sample analysis information, we get the visual porosity for reservoir rock formation in several geological structure. Based on that, we make the geological modelling where the potential reservoir and the source rock around our interest area.

1. Introduction

Early efforts realized that MT was a potential tool for imaging conductive sedimentary rocks beneath thrust sheets of more resistive rocks such as volcanics overthrust (Anderson and Pelton, 1985). Several previous studies show how the effective using MT in clastic sedimentary rocks. Such as, the case study in Papua New Guinea by Christophersen (1991) that have a thick layer of clastic sedimentary rocks beneath 1-2 km of heavily karsted limestone. In volcanic zone, igneous rock that created by the solidification of magma have been ignored because of perceived lack of reservoir quality (Farooqui MY, et all, 2009). However, igneous rock can develop porosity and permeability (Srugoa P and Rubinstein P, 2007) by the activity that can influence every aspects of petroleum system, providing source rock, affecting fluid maturation and creating migration pathways, traps, reservoirs and seals (Schutter SR in Petford N and McCaffrey, 2003).

Source rocks results from a convergence of physical, biochemical and geologic processes that culminate in the formation of fine-grained sedimentary rocks containing carbon and hydrogen-rich organic matter (McCarthy K et all, 2011). Most hydrocarbons found in volcanic rocks come from sedimentary source rock, some volcanic rocks are also source rocks. Vegetation entrained in ash flows may contain enough water to protect it from the heat of emplacement (Farooqui MY, et all, 2009). The organic matter of it slowly cooks as pressure and temperature increase with the burial depth. Given
sufficient heat, pressure and time and the organic matter contained within transform into kerogen. (McCarthy K. et all, 2011).

Some petroleum compounds within source rocks are released at temperature lower than those needed to break down the Kerogen (McCarthy K. et all, 2011). By monitoring the compounds of organic material, geochemical testing information of outcrop samples, formation cuttings, sidewall cores and conventional core can determine the amount of generated petroleum relative to a rock’s total potential such as the type and thermal maturity of organic matter present in the rock. This study will show the source rock and reservoir potential from the geochemical information and apply it to magnetotelluric method by combine the 2-D MT modelling and inversion with geological structural data.

2. Materials and methods

In this research, we used 132 MT data points divided with two line at exploration area. There are Line-2 with 70 data points and line-3 with 62 data points. Each data have one kilometer interval. Line-2 is parallel with line-3 from North-East to South-West.

The geochemical information is from the previous study that Pertamina did. There are including kerogen types index, kerogen composition index and the maturity index. The kerogen types index is from TOC versus S2. The kerogen composition index is from the fluorescene amorphous and lipthine and hydrogen index versus Oxygen Index that shows in modified of van krevelen diagram.

There are some steps for doing MT data processing. First, we used time series correction to reduce noise signal with SSMT2000. Second, we used crosspower correction to make each data points become smooth data by MT Editor and show the correct trends of the structure. After that, we used inversion of Magnetotelluric (MT) data that had been corrected to make a resistivity mapping and modelling by using Winglink.

We make an interpretation of geological structure by combining it with additional data, such as geological map data. The geological map can describe the structure and the formation information. Meanwhile, the source rock potential from the geochemical information and hydrocarbon reservoir potential from the core data sample information will describe the visual porosity in several formation.

3. Results and discussion

According to the previous study that Pertamina did, the geochemical data information show the TOC results of Ciletuh formation. Total organic carbon (TOC, wt. %) describes the quantity of organic carbon in the rock sample and includes both kerogen and bitumen. (Peters and Cassa, 1994). The kerogen types index show (figure 1) the Ciletuh formation is in the type III kerogen that derived primarily from terrigenous plant debris, which has been deposited in shallow to deep marine environments.
TOC indicates the quantity, but not the quality, of the organic matter. Meanwhile, S2, corresponds to the hydrocarbons that evolve from the sample during the second programmed heating stage of pyrolysis. These hydrocarbons results from the cracking of heavy hydrocarbon and from the thermal breakdown of kerogen. S2 represent milligrams of residual hydrocarbon in one gram of rock, thus indicating the potential amount of hydrocarbon that the source rock might still produce if thermal maturation continue (McCarthy K. et all, 2011). Figure 2 show TOC versus S2 which have Type III kerogen that contain the residual hydrocarbon. The type III kerogen has lower hydrogen and higher oxygen content (figure 2) than types I or II; consequently, it tend to generate dry gas (figure 3).

In the other hand, the MT data inversion show the resistivity variation of the formation structure. Based on that, we combine it with the geological section map and show the model that represent several main formation. The inversion and interpretation of the Line-2 show (figure 4) the Gabon Faults that separated Ciletuh Formation and Penosogan Formation. The interpretation model of line-3 (Figure 5) show the Gabon Faults with the intrusion that separated Ciletuh Formation and Penosogan...
Formation. This intrusion can make an effect for the maturity of the source rock in Ciletuh Formation. The maturity of the source rock will increase by the time and flowing to the potential reservoir area such as in the Jampang Formation (Tomj) that have sandstone, limestone and tuff in the syncline area rounded with anticline of the Ciletuh formation.

Based on the results from the inversion of MT data and the additional data for support the interpretation, we can see the indicate of the hydrocarbon reservoir in some enable geological area. S for Source rock and R is potential Reservoir. According to geochemical information and the geological structures, the source rock is around the Ciletuh Formation and the potential reservoirs divided with several formation of sedimentary rock. There are Jampang Formation (Tomj), Bentang Formation (Tmb) and Pamutuan Formation (Tmpa). According to the colors of those figures, the colors around green and blue representative of sedimentary rock that have potential reservoir with the resistivity value around 170-370 Rho (Ohm.m).

**FIGURE 4.** Interpretation model of line-2. The geological modelling section overlay with 2D inversion MT Data

**FIGURE 5.** Interpretation model of line-3. The geological modelling section overlay with 2D inversion MT Data
4. Conclusions

The conclusion of this study show the resistivity mapping model that can be used for geological structure interpretation, especially in volcanic area zone with some additional data for support it, such as geochemical information. The interpretation of line-2 and line-3 show geological structure with the source rock and potential reservoir around the interest area. The identification of the hydrocarbon reservoir depend on source rock potential and the visual porosity from the core data sample. According to the limitations of MT method in the early days of its application to hydrocarbon exploration, the method will be more effective in certain niche environments.

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