Self–Potential Methods on Geothermal Exploration (Case Study: Mount Patuha, West Java, Indonesia)

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***Abstract*—**The purpose of this study is to interpret self-potential data by analyzing of the curve shape, contour, and positive-negative value of self potential polarization anomalies. The results are used to estimate the direction of fluid movement in subsurface at the geothermal field. The study was conducted in the area of Mount Patuha, West Java, Indonesia. This area is an area that is estimated as a prospect of geothermal energy. Measurements were conducted using amplitude of potential at the position of reference point in the Kawah Putih with a height of about 2200 m above sea level. Electrode moves with the observation point of 10 m distance. From this study, the results obtained that the ground water movement around the Kawah Putih is to the northeast trending.

Key words—curve shape**,** self potential polarization anomalies, geothermal energy, ground water.

I. Introduction

Self-potential is a passive geophysical method that measures the natural potential of the earth (Nyquist, 2003). This method is called passive because it does not give any disturbance to the earth. Potential measurements are made between two points on the surface of earth's surface. First, self-potential method was proposed by Robert Fox in 1830 (Reynolds, 1997) by using a copper plate electrode with a measuring device for detecting the galvanometer copper-sulfide deposits in Cornwall, England. Self-potential method has been used since 1920 as a complementary application in the exploration of metal deposits. The main factor affecting the value of self-potential variation is the presence of ground water. Potential flow is caused by ground water, either as a solvent of the electrolyte or other minerals.

The natural potential of the earth surface consists of two components, one is constant and the other is time varying. Constant component is caused by electrochemical processes, and by components that change due to variations of the potential difference of alternating current (ac) induction, i.e. by an electrical storm and the variation of Earth's magnetic field. Each component of the self-potential are called mineral potential and the background potential.

II. Basic Theory

Electrokinetic's Potential (Ek) arises as a result of the electrolyte movement through a porous or capillary slit. Potential is measured along the capillary. Generated potential from this process are usually categorized as electrofiltration, electromechanics, and streaming potential which can be expressed as follows:

$$Ek = \frac{\varepsilon \mu C_E \delta P}{4\pi\eta} \qquad (1)$$

where ε, μ, $\eta, \delta P$, and C_E are the dielectric constant, resistivity, dynamic viscosity of the electrolyte response, the changes of pressure, and the coupling coefficient of electrofiltration respectively. C_E represents the physical and electrical properties of the electrolyte which passes through the medium. The electric current occurs because of the hydraulic gradient and the quantity of electrofiltration coupling coefficient (C_E). This current shows the physical and electrical properties of the electrolyte. The movement of fluid through a medium will generate a potential gradient along the flow path as a result of the interaction between pore fluid movement and two layers (Overbeek, 1952). This potential is called the streaming potential.

The surface of the ore mineral always has a negative electrical charge, so that pulls the positive ionic charge around the pore water and formed electrical double layer. The layer will be cut off if the pore water moves due to pressure gradient. The result is a separation of charge and electrical potential difference between the upstream and downstream in the pore. The number of electrical potential difference is caused by water absorption that depends on the potential gradient and conductivity of pore water pressure. Some data indicate that there is a relationship between ore minerals coupled and the conductivity as a result of pore space in soil with ore mineral that produces electrical double layer. The earth material is influenced by internal erosion in the overall of pore space. The streaming potential increases by increasing influence material.

The case of coupled electrokinetic, coupled fluid flux, and current induced density can be expressed as follows (Meilawati, 2011 and Sill, 1983):

$$J_E = -(\kappa\varepsilon\zeta/\eta)\nabla\phi - (K/\eta)\nabla P \quad (2)$$

$$I_E = -\kappa\sigma\nabla\phi - (\kappa\varepsilon\zeta/\eta)\nabla P \quad (3)$$

where I_E is the electrical potential gradient and $\nabla\phi$ is the pressure gradient. The parameters σ, ε, and η are the electrical conductivity, dielectric constant, and viscosity of the fluid respectively. κ and K are the porosity and permeability of the medium. ζ is the zeta potential which is the voltage across the double layer. The first and the second component of equation (2) shows the flux of fluid flow from electro-osmotic effect and Darcy's law, whereas in the first and second component of equation (3) shows the electrical current density and potential resulting from Ohm's law.

In some mountainous areas, the rain water can seep in every different geological layers, it is depending on the value of permeability. The downward flow is usually interrupted by impermeable layers. Geological topographic influences the flow of water due to gravity where the potential increases when the topographic height decreases. Usually it is written as a negative relationship (mV/m) or (mV/MPa) as a coupled electrokinetic coefficient. The coefficient has a value ranging between -1 and 10 mV, with an average -2mV.

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Interpretation of Self-Potential Anomalies

Self-potential anomalies data can be interpreted qualitatively and quantitatively, depending on the purpose of the research. The number and quality of data, the additional data structure which contains information of geology and hydrology, as well as the available computing facilities determine the self-potential. Self-potential anomalies are often interpreted qualitatively by the shape of the profile, amplitude, polarity, and contours pattern. General qualitative self-potential is indicated by some of parameter of physics.

III APPLICATION OF SELF-POTENTIAL METHOD IN GEOTHERMAL EXPLORATION

At fist self-potential method is used to determine the areas of mining prospects (Sato, 1960, Telford, 1990). But along with the development of science and technology, the self-potential can be used to investigate the prospects of geothermal areas (Corwin, 1976, 1979, 2000).

Application of self-potential method in geothermal exploration is based on electrokinetic process mechanism where an electrolyte fluid flowing in porous media are experiencing separation and accumulation of electric charge. Measurement of self-potential from electrokinetic potential for geothermal exploration has been done in the flow mapping of hydrothermal circulation zones below the earth's surface (Yasukawa, 2000), which attempts to describe the fracture and fault zones. In addition, self-potential method has been widely used for monitoring of geothermal production and injection wells. It is also used in the study of the process of hydraulic fracturing in geothermal reservoir through the monitoring of self-potential anomalies (Kawakami, 1994).

A qualitative study of self-potential anomalies due to water flow in soil has also been done (Vichabian, 2002). Their prediction results indicate that the presence of water movement in soil can lead to self-potential phenomenon. The vertical movement of water that seeps generate positive value of self-potential can lead to greater self-potential change for the greater distance.

IV SELF-POTENTIAL DATA ACQUISITION

In this study, measurements were conducted at the Kawah Putih, Mount Patuha, West Java. Kawah Putih is at altitude of approximately 2200 meters above sea level. Patuha is an andesitic stratovolcano mountain type. Geologically, the mountain is part of the Patuha active Sunda arc, which is formed from India-Australia plate subduction beneath the Eurasian plate (Layman, 2003). Volcanism in this region originated from the Upper Pliocene and Lower Pleistocene that gave a unique system of volcanoes and crater lakes. Placement of observation points is shown in Figure 1. Kawah Putih has a width of approximately 300 m to the water lake with temperature about 26-34^o C. This crater contains acid with pH 0.5-1.3, 2500-4600 ppm of sulfur and 5300-12600 ppm of Cl content.

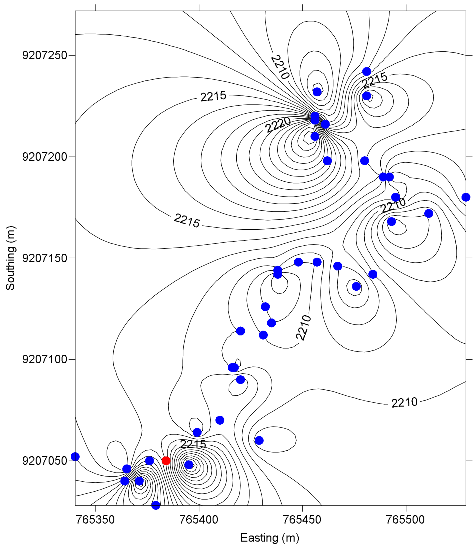


Figure 1. The point of self-potential measurements: Base (red) and observation point (blue).

The potential gradient method uses two electrodes to move the fixed distance approximately 5 m or 10 m. The observation point is the midpoint between two electrodes with units of mV/m unit. In this study, the used method is the potential amplitude method. Measurement of self-potential at Kawah Putih has about 41 points. The used Equipment in the data acquisition is a digital multimeter, porous pots, copper electrodes, cables, CuSO4, GPS and spades.

V DATA PROCESSING

The data was made in the coordinates (longitude and latitude) form. The measured data was corrected with base point (reference) and elevation. The gridding data process is carried out using krigging. The results are arranged in three slicing (A, B and C) as shown in Figure 2.

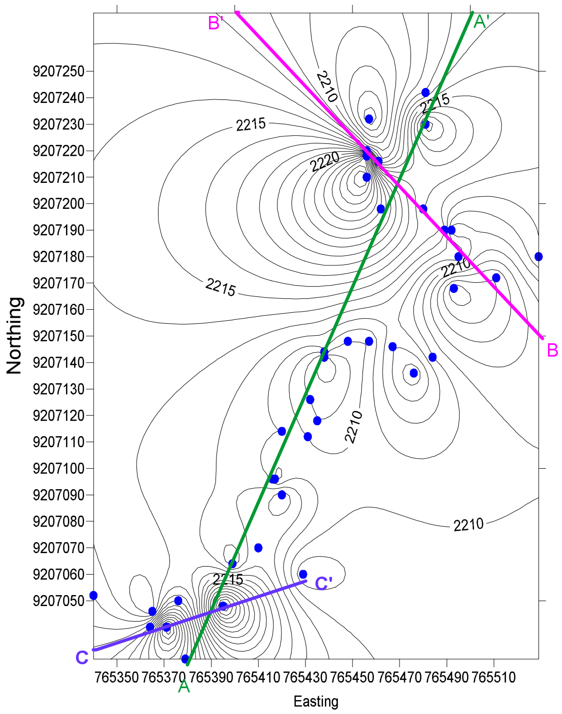


Figure 2 Licing line A, line B and line C

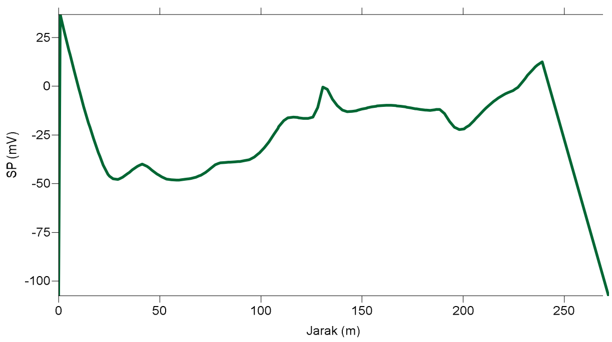


Figure 3. The graph line A after correction.

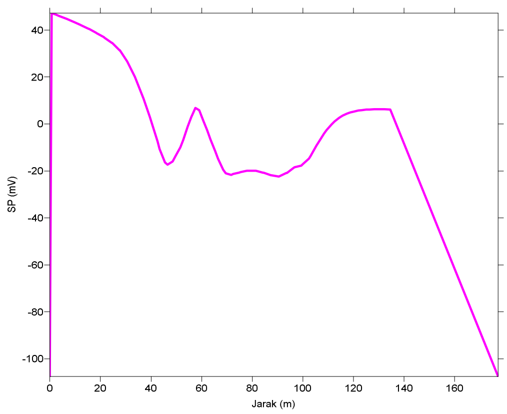


Figure 3 The graph line B after correction.

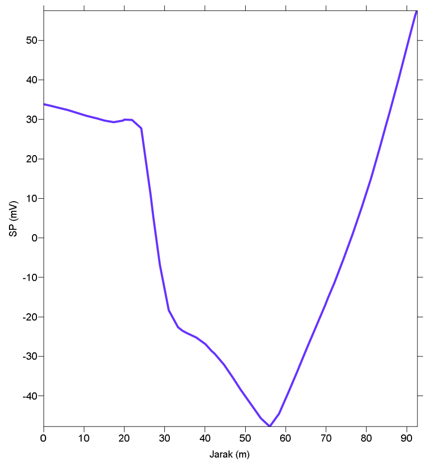


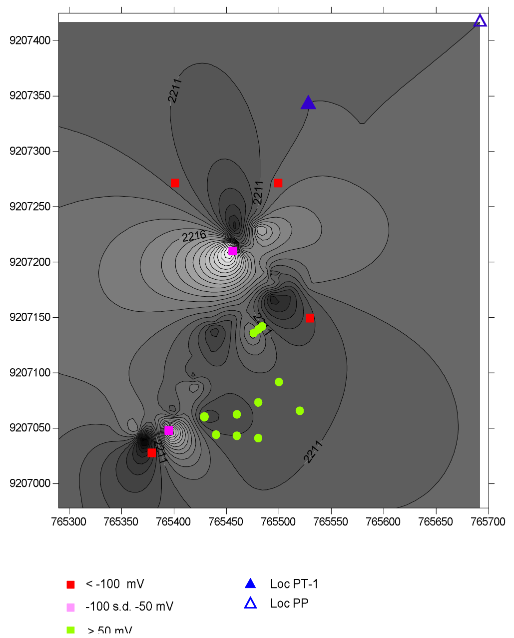
Figure 4 The graph line C after correction.

VI. INTERPRETATION

After data acquisition and data processing, the SP values were corrected in elevation, 2199 m to 2228 m of -107.49 to 82.94 mV. Self-potential anomalies vary in value according to its source (Reynolds, 1997). If the value of self-potential is negative of hundreds millivolts, then the source is likely sulfide ore deposits, deposits of graphite, magnetite and conductive minerals, coal or manganese. If the self-potential positive of tens millivolts, then it is likely the source of quartz veins or pegmatite. If the self-potential value is less than 100 millivolts, it is probably due to chemical reactions. If the self-potential is positive or negative of one-hundred millivolts, the cause is the movement of ground water. If the self-potential is negative value of three hundred millivolts, the cause is bioelectric (trees and plants).

The result of this research shows that the self-potential values vary between -107.49 to 35.77 mV at a distance of approximately 270 m on line A or approximately 9,207,270 N and 765 550 E. This result can be interpreted that there is a movement of ground water due to silting of sulfur near the crater where the remnants of the sulfur production come from the crater lake sediments.

In line B, the value of self-potential is between -107.49 to 47.16 mV. At the beginning point of line B or approximately 9207150 N -765 520 E and the end of the line B or approximately 9207270 N - 765 395 E constitutes the self-potential less than -100 mV. These results show the movement of ground water caused by sediment sulfide similar to line A. In line C, the value of self-potential ranged from -47.8 to 57.51 mV. For a starting point for distance of about 25 m or at position 765,340 E and 9,207,032 N to 765,363 N 9207040 E, self-potential value reduces from approximately 35 mV to 30 mV, then decreases sharply up to the -47 mV and then increases up to 57.5 mV. The range of self-potential on line C is in the normal value. Declining value of self-potential sharply indicates a possible fracture zones that are filled by fluid.



Self-potential anomalies can be seen in the base of measurement and ground water data (Figure 5). Based on the chemical reaction due to soil water movement and also by looking at the drilling location at existing well, the movement of ground water could actually trend in all directions. However, based on the red dot and green dot, the location of existing wells and location of planned wells, the movement of ground water is estimated northeast as shown in Figure 6. This is because there are the red dots with self-potential value less than -100 mV which shows the movement of ground water and green dots with self-potential values greater than 50 mV which indicates the existence of chemical reactions due to the movement of ground water.

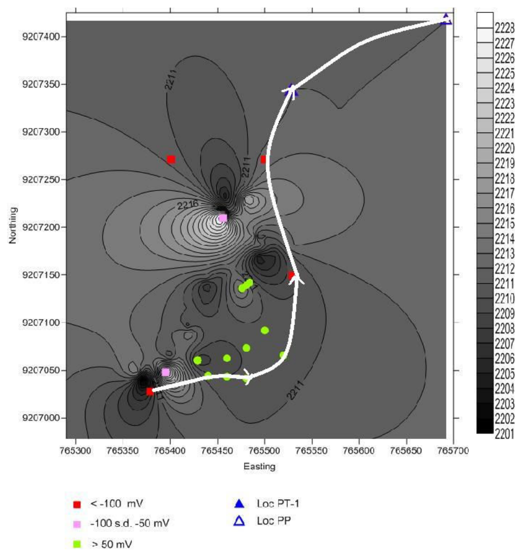


Figure 6 The estimated direction of groundwater movement.

Ground water moves through the pores of rock or fracture zone. This is because there are red dots with self-potential value less than -100 mV, which shows that the movement of ground water and green dots with self-potential values greater than 50 mV that indicates the existence of chemical reactions due to the movement of ground water.

VII CONCLUSION

Study about measurement of self-potential method can be applied in geothermal exploration to estimate the fluid direction below the earth's surface. In this study, the direction of groundwater movement in the area of Kawah Putih is northeast. Sources estimated to be in the southwest because at that point there are hot rocks. This is evidenced by the existence of another study that says that the negative magnetic anomaly in point southwest point.

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