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DETERMINATION OF THE DIRECTION OF HOT FLUID FLOW IN CANGAR AREA, ARJUNO-WELIRANG VOLCANO COMPLEX, EAST JAVA USING SELF POTENTIAL METHOD

PENENTUAN ARAH ALIRAN FLUIDA PANAS DAERAH CANGAR KOMPLEKS GUNUNG ARJUNO-WELIRANG, JAWA TIMUR DENGAN MENGGUNAKAN METODE POTENSIAL DIRI

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Abstract

Research with self potential method has been done in Cangar area of Arjuno-Welirang volcano complex, East Java. The purpose of this study was determined the direction of hot fluid flow. This hot fluid forms a geothermal manifestation of hot springs. Data acquisition has been done using fixed electrode configuration with interval 5 meters in 5 lines. In this configuration there are two porous pot electrodes, one of them set in fixed station and the other as mobile station. Based on the potential distribution value of the isopotential map, the lowest potential value about -54,5 mV and the highest value about 89,4 mV, so that in Cangar area can predicted the direction of hot fluid flow from southeast to northwest. Based on the results of this research in the direction of hot fluid flow can provide information about hydrothermal system in Cangar area for study of geothermal potential of Arjuno-Welirang Volcano complex, East Java

Keywords: *self potential, fixed base configuration, isopotential map, fluid flow*

Abstrak

Penelitian dengan menggunakan metode potensial diri telah dilakukan di daerah Cangar kompleks Gunung Arjuno-Welirang, Jawa Timur. Tujuan penelitian ini adalah untuk menentukan arah aliran fluida panas. Fluida panas ini membentuk manisfestasi panas bumi berupa sumber air panas. Akuisisi data menggunakan konfigurasi elektroda tetap dengan jarak antar elektroda porous pot 5 m sebanyak 5 lintasan loop. Pada konfigurasi ini terdapat dua elektroda porous pot yaitu satu tetap dan yang lain berpindah. Berdasarkan nilai sebaran potensial dari peta isopotensial didapatkan nilai potensial terendah adalah -54,5 mV dan nilai yang tertinggi adalah 89,4 mV, sehingga pada daerah Cangar dapat diprediksi arah aliran fluida panas dari tenggara menuju barat laut. Berdasarkan hasil penelitian ini berupa arah aliran fluida panas dapat memberikan informasi mengenai sistem hidrotermal daerah Cangar untuk studi potensi panas bumi kompleks Gunung Arjuno-Welirang, Jawa Timur.

Kata kunci: *potensial diri, konfigurasi elektroda tetap, peta isopotensial, aliran fluida*
PACS: 91.65.My, 93.85.Jk

I. INTRODUCTION

Geothermal is a natural resource which is produced by rocks interaction and hot fluid flow inside the earth. Indonesia has 40% geothermal potency of the earth [1]. Based on latest survey of Geological Agency of Indonesia, Ministry for Energy and Mineral Resources (Badan Geologi, Kementerian Energi dan Sumber Daya Mineral), Indonesia has 331 geothermal spots spread in 30 provinces. Currently, geothermal utilization reaches only 1,698.5 MW or about 9.3% of total geothermal reserves of Indonesia [2].

East Java has 11 geothermal potencies and produces energy of 1206,5 MW. One of area geothermal potential in East Java is located on Welirang Volcano located in the Arjuno-Welirang Volcano complex. At Welirang Volcano suspected geothermal energy stores are characterized by the emergence of geothermal manifestations in the form of hot springs [3]. Hot water source is one of them located in the area of Tulungrejo Village Cangar Bumiaji Batu City. Geologically, the rocks in this area are dominated by volcanic rocks of lava and pyroclastic quarterers. There are several fault structures and ring fractures that develop in the area with dominant structures [4].

There have been several types of research to know the geothermal potential with geoelectrical resistivity and geomagnetic method. Based on the results of research with geoelectrical resistivity method indicate the existence of geothermal potential located in the south of Cangar hot springs with a depth of 24.7 meters from the ground surface [5]. Based on the geomagnetic method indicates the existence of geothermal potential located in the north and west of the Cangar hot water manifestation [6]. Geothermal potential research on hydrothermal systems in Cangar area is not known for certain. This hydrothermal system includes hot fluids that form geothermal manifestations of hot springs. The direction of the distribution of hot fluid is important in research for determining the geothermal potential. This is the object of geothermal research in the form of hydrothermal system investigation related to the direction of hot fluid flow by using self potential method

The self potential method is a passive geophysical method that measures the Earth's natural static potential [7, 8, 9]. Potential measurements are made between two points above the earth's surface. This method is based on self potential measurements of rock sedimentary mass in the earth's crust without injecting electrical current into the ground [10]. The emergence of self potential is due to mechanical and electrochemical processes.

In the beginning, self potential methods are used to determine areas that contain minerals. As science and technology develop, self potential methods can be used to investigate geothermal areas including to know the flow of sub-surface heat fluids. The self potential method can also be used to detect a geothermal reservoir [11]. This geothermal reservoir can be a geothermal fluid flow beneath the surface that forms a hydrothermal system in geothermal potential areas. Several studies have been conducted to detect the direction of the sub-surface heat fluid flow, where the flow of sub-surface fluids causes self potential anomalies [8,12].

The use of self potential methods in geothermal exploration is based on the mechanism of electrokinetic in which the electrolyte fluid flows in a porous medium. Electrokinetic (streaming potential) occurs when the electrolyte solution in the rock pores flows. The basic theory of electrokinetic potential (electrophilation or streaming potential) was first proposed by Helmholtz. Hydrostatic pressures δP will generate electric potential difference δV, this relationship is known as Helmholtz-Smoluchowski equation [13]:

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

with ε is the dielectric constant, μ is the resistivity of the electrolyte, η is the dynamic viscosity of the electrolyte, δV the electric potential difference, δP is the hydrostatic pressure difference, and C_E is the coefficient of the electrophilation pair. Based on the above equation then the fluid flow will be in the direction of electric current.

The advantage of self potential methods over other geoelectrical methods is highly responsive to conductive subsurface targets such as metallic minerals and sulfide minerals, and can be applied to areas with flat topography [13]. In addition the self potential method is passive so it will not disturb the physical parameters to be measured in the form of natural static potential [13]. In this research, geothermal reservoir in the form of hot fluid flow which is a research target located in the geothermal prospect area of Arjuno-Welirang Volcano Complex, which is around Cangar hot water source, Bumiaji Kota Batu East Java.

II. RESEARCH METHOD

The research was conducted on 5-9 November 2016 located in Cangar area of Arjuno-Welirang Volcano complex, Bumiaji Batu ,East Java. Data processing is done in Geophysics Laboratory of Department of Physics, Brawijaya University of Malang. The location of research can be seen in Figure 1 is the area marked red box.

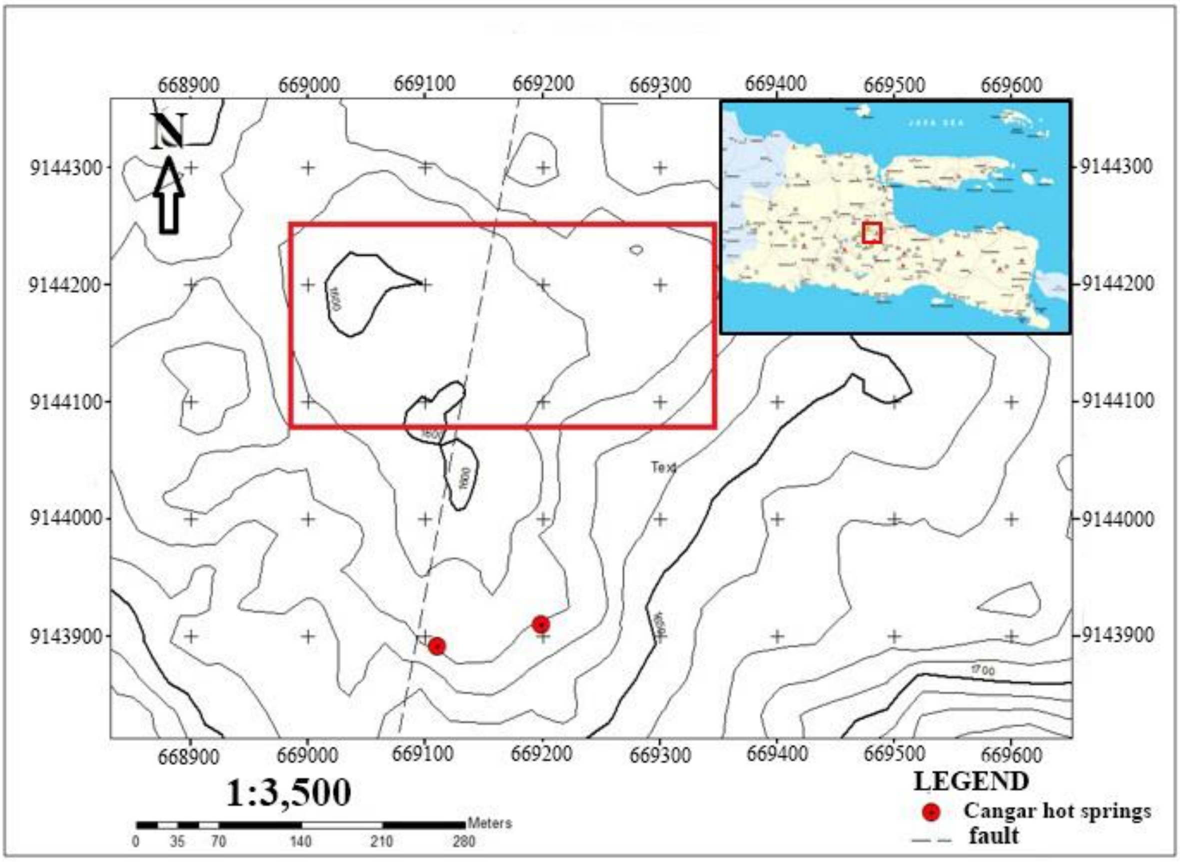

Figure 1. Map of Research Location at Cangar Area on Mount Arjuno-Welirang Complex, East Java

Data Acquisition

The acquisition of self potential method has several steps that need to be implemented before and when the measurement takes place. Stages before measurement involve making a survey design map for the determination of measuring point and equipment preparation. While the stage when the measurement takes place includes the calibration of tools and data retrieval in accordance with the design map of the survey has been determined.

The first stage of the acquisition process is the creation of a survey design map. The design of the survey design map aims to know the boundaries of the area to be surveyed and the measurement targets can be met. The survey design in this study is as follows:

In Figure 2 there are red dots that illustrate the point of measurement. In this study used closed loop system in the process of capturing potential data. This closed loop system means that potential data capture starts at a point and will end at that point.

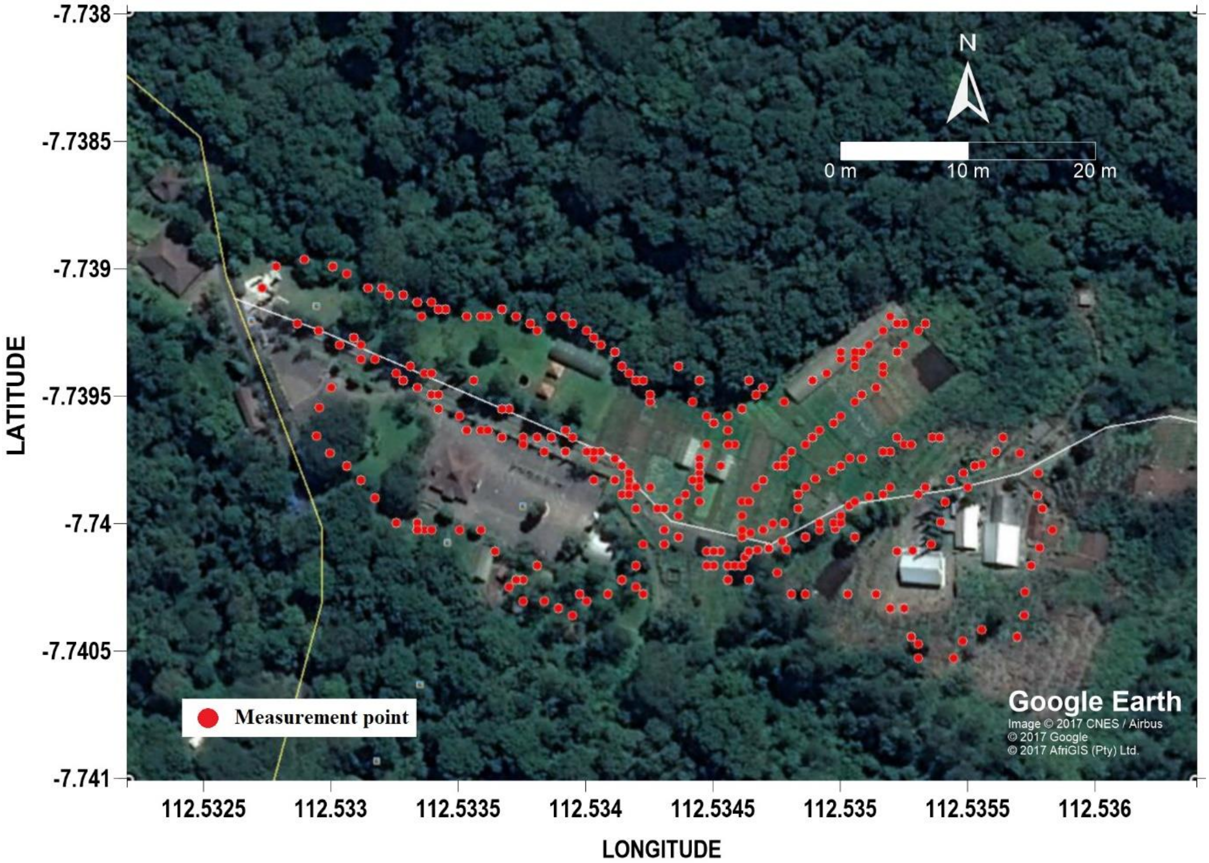

Figure 2. Design of Survey Research

The second stage is a calibration tool with the aim to get good data. Calibration is performed on porous pot electrode by planting both porous pot electrode into the soil with a relatively close distance (± 10 cm). Then the potential value is measured using a digital voltmeter with the result obtained to be close to zero and a maximum of 2 mV. When the measured potential value exceeds 2 mV, the porous pot electrode must be cleaned which is then recharged with $CuSO_4$ solution of the same concentration.

The third stage is the data retrieval process using a digital voltmeter that has high input impedance to ignore current from the earth during the measurement process. The porous pot electrode configuration used in this study is the fixed base configuration by keeping one electrode fixed at one point, while the other electrode is moving in the direction of the predetermined trajectory (Figure 3). The advantage of this configuration is that the measured potential is always continuous against the reference point, so zero error between the two electrodes does not occur (10). The distance between porous pot electrodes used in this study is 5 meters.

The data collection of self potential method is done in two ways, namely as a function of time (base) and the function of distance (rover). The measurement of the time function (base) is done by placing a pair of porous pot electrodes in a fixed place. The collection of potential data on the base is based on the variation of time, in which the potential data is collected every 5 minutes without moving. The assumption used is that the point measured has a change in potential value over a given time range. Data retrieval as a function rover is performed along the predetermined path of the survey design with a pre-defined configuration. The assumption used is the point that has been measured is considered not to change the potential value. To obtain an isopotential map, the measurement point is distributed in the form of a regular grid or trajectory.

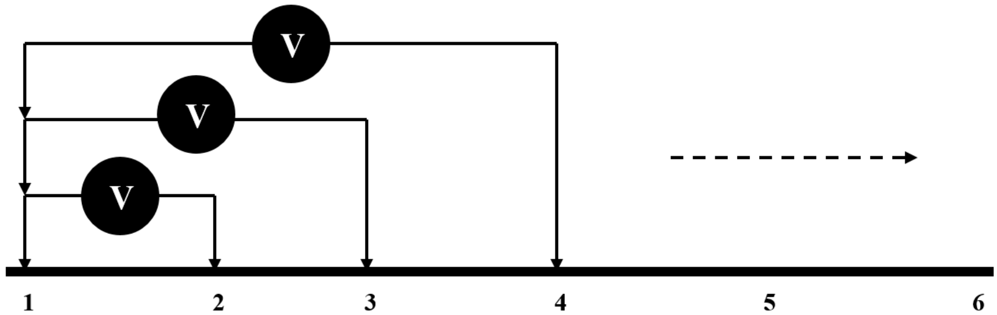

Figure 3. Technique of Data Acquisition of Fixed Base Configuration

Data Processing

The data obtained from the acquisition process is a potential value between two porous pot electrodes read in a digital voltmeter. These potential data have not shown the true potential self-value, since there are differences in values at a measuring point if the measurements are repeated at different times. Therefore, the potential data of the measurement result must be corrected. Corrections made in this study include diurnal correction, reference correction, and closure correction. Corrected potential data is assumed as potential data from anomaly causing objects, in which the hot fluid flow is targeted.

Data Interpretation

Corrected self potential data is interpreted qualitatively by using Surfer 13 software to obtain isopotential contour maps. Based on this isopotential map, it can be interpreted geothermal fluid flow direction of research area.

III. RESULTS AND DISCUSSION

Measurement of self potential method has been done in geothermal prospect area of Arjuno-Welirang Volcano complex. The selected location is the area around Cangar hot spring, Bumiaji Batu East Java as one of the geothermal manifestations of the Arjuno-Welirang Volcano complex. The number of measurement points in this study is 279 points with the distance between points 5 meters. This study focused on detecting the direction of the geothermal fluid flow of the research area.

The potential data that has been obtained is being used to made contour map using Surfer 13 software by entering the coordinates (latitude and longitude) and potential data. Figure 4 shows that the measured potential value of the study area ranges from -99.3 mV to 67.8 mV. These potential data have not shown the true potential self-value, since there are differences in values at a measuring point if the measurements are repeated at different times. Therefore, the potential data of the measurement result must be corrected. The first correction is a diurnal correction. This diurnal correction is performed to eliminate measurable telluric currents during the data retrieval process. The result of potential data that has been performed daily correction is shown in Fig. 5. Based on Fig. 5 when compared with Fig. 4 there is still a slight change of contour, where the daily corrected potential value is between -97.98 mV up to 66.7 mV.

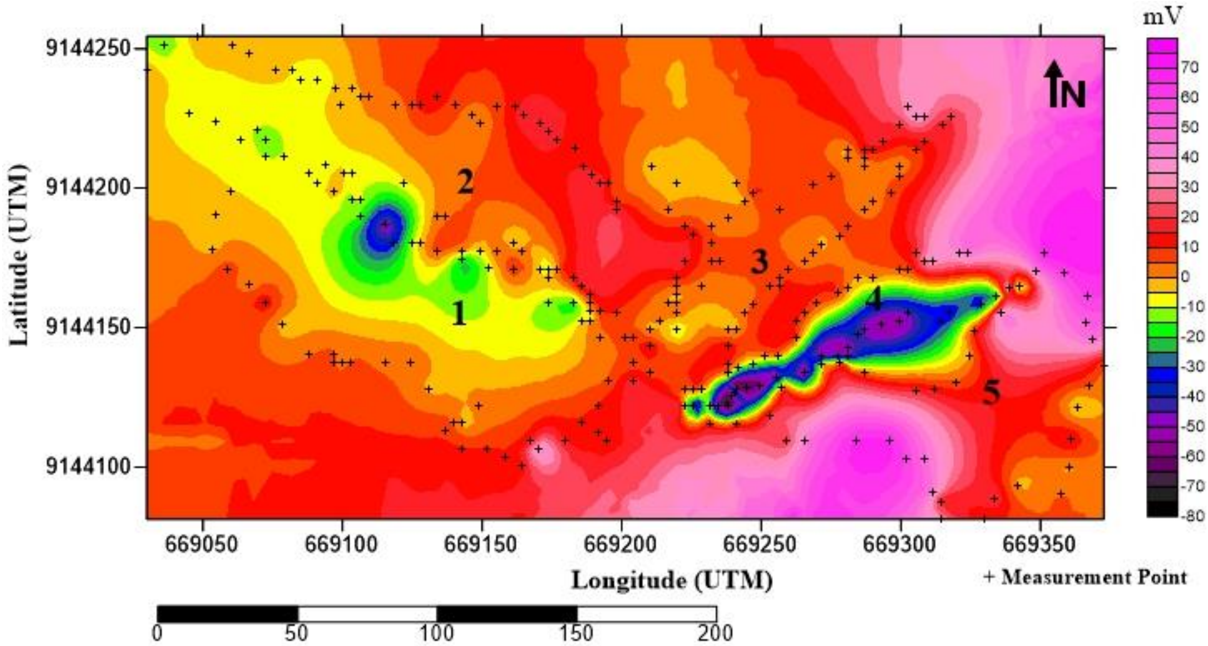

Figure 4. Contour Map of Measurable Potential Distribution

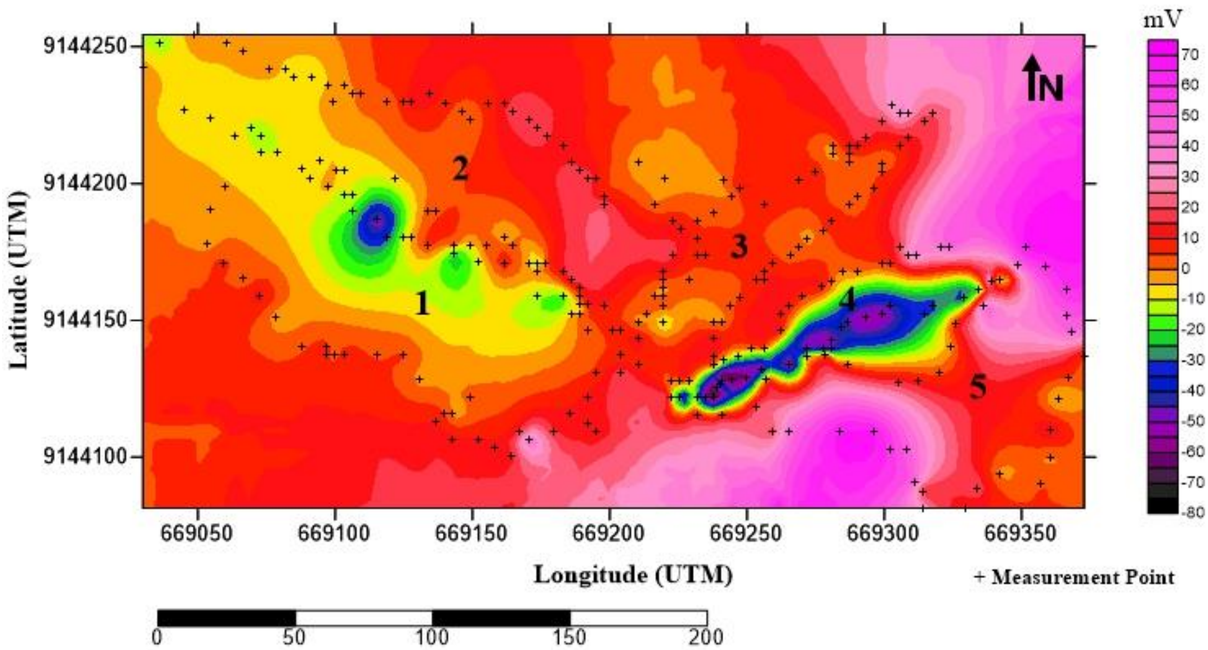

Figure 5. Contour Map of Potential Diurnal Corrected Spreads

Figure 6 is the contour of the reference correction calculation. This reference correction is made to combine different sections of the same SP profile by correcting the various changes of the reference electrode. Each time the measured electrical potential difference from the new reference measurement is resumed from 0 mV, but in reality the measured field measured potential value is not 0 mV.

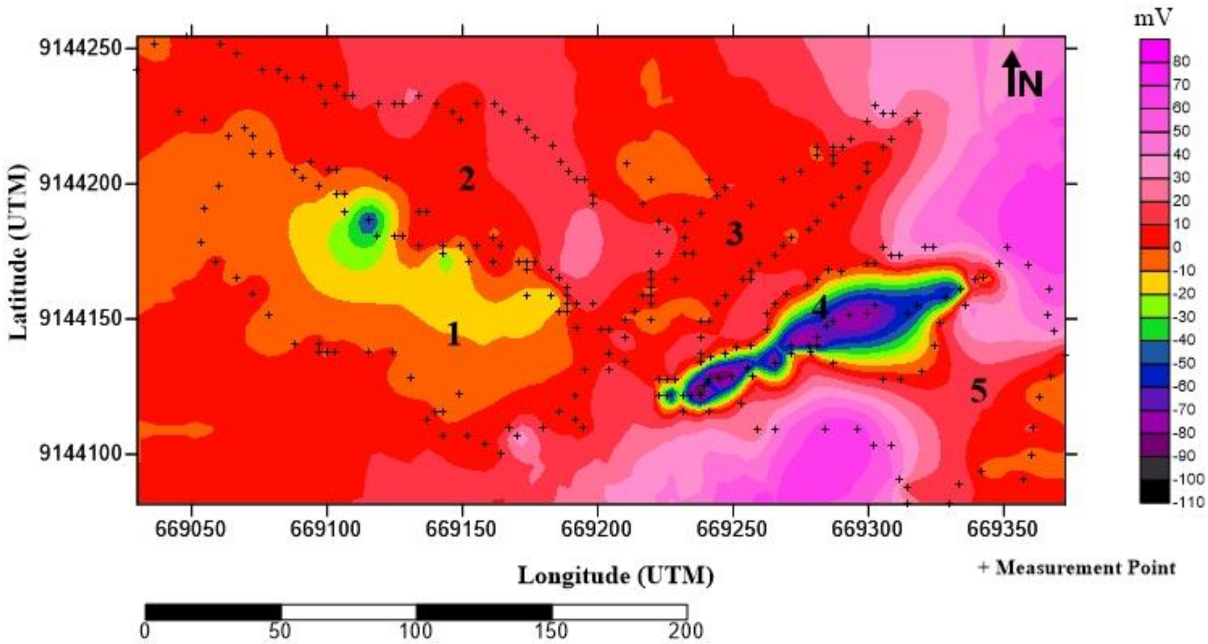

Figure 6. Contour Map of Potential Reference Corrected Distribution

In the case of a closed profile, the first point will be identical to the last point so that the measured potential value will theoretically be equal. This will be evident if there is no interference with the environment when the measurement at the first and last point is done. However, during the data retrieval process, the measurement conditions may change like soil moisture, soil temperature, tool error, and drift will be observed.

Drift is considered to be increased regularly from the first and last point during the time period of the acquisition. This drift is considered as noise so it must be done a correction called closure correction. The result of this correction is made contour map which hereinafter referred to as isopotential map (Figure 7). The isopotential map illustrates the potential spread of self potential that has been corrected in the study area. The results of this study indicate that the potential values vary between -54.5 mV to 89.4 mV. This potential arises because of the electrokinetic process under the surface. Based on the isopotential map can be interpreted that the research area is a conductive zone. This can be seen by the measured low potential value which is negative.

The lowest potential anomaly zone in the study area is found in the northwest region or line 1 with a potential value of -54.5 mV. This track 1 is the most negative zone in the research area. It is suspected that in the zone there is a source of sub-surface heat fluid flow. In line 3 also found the potential value of negative value. This indicates a possible accumulation of sub-surface fluid flow from the southeast to the northwest.

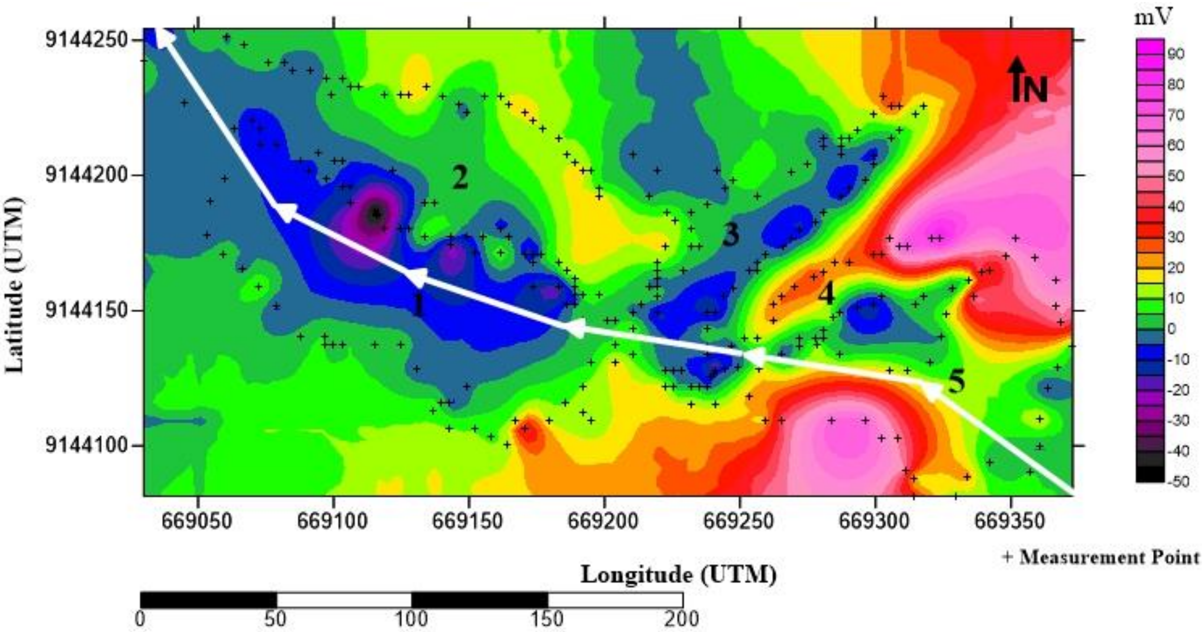

Figure 7. Isopotential Map of Study Area

Based on the isopotential map, the predicted direction of the Cangar sub-surface hot fluid flow from the southeast to the northwest, on the map is indicated by a white arrow. It is based on the low potential value of negative value. Based on previous studies [14] suggesting that the smaller the self potential or negative anomaly value, the accumulation of fluid flow to a region is relatively large. In addition, self potential anomalies are also influenced by topography that directly influences fluid flow control [15]. Research areas in the east and southeast have higher topography. Based on the fluid flow properties flowing from high to lower, the flow of hot fluid in the research area from the southeast to the northwest corresponds to the higher topographic conditions in the southeast. Given the predicted findings the direction of the sub-surface fluid flow will be helpful for further research on geothermal potential in the Arjuno-Welirang Volcano complex, East Java.

IV. CONCLUSION

Based on the results of data processing and isopotential contour map that the research area is a conductive zone that can be seen from the low measured potential value. The highest potential value of this study was 89.4 mV, while the lowest potential value of this study was -54.5 mV. The direction of the Cangar sub-surface hot fluid flow is predicted from the southeast to the northwest based on the isopotential and topographic maps of the study area. Based on these results can provide information about the hydrothermal system in Cangar area for the study of the geothermal potential of the complex of Arjuno-Welirang Volcano Complex, East Java.

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