CAPROCK AND RESERVOIR INTERPRETATIO OF ARJUNO-WELIRANG GEOTHERMAL SYSTEM FROM 2D MT AND 3D GRAVITY MODEL

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ABSTRACT. This study was conducted to model the geothermal system Arjuno-Welirang northern part from the MT and gravity data. MT modeling done in 2D and gravity in 3D. From 2D MT model of North-South trending shows model 2 layer resistivity, ie resistivity low (<10 Ohm.m) associated with basalt lava rock with clay mineral alteration and an alleged caprock. And layer with moderate resistivity (60-100 Ohm.m) associated with the Lower Quaternary andesite-old who is the reservoir system.

Distribution of Bouguer anomaly reflects the lithology of rock on the surface. Relatively low anomalies in the North (25-28 mGal) allegedly associated with pyroclastic flows. High anomaly in the South (> 43 mGal) associated with Mount Anjasmoro products spread to the South West section with the composition of andesitic-basaltic lava. 28-40 mGal anomalies are thought to relate to Lava Welirang I spread toward the center of the North with the composition of basalt lava. From 3D models Bouguer anomaly inversion results show a layer with a density of 1.49 gr/cm3 - 2.4 gr/cm3 with clay type material which is suspected as caprock, located at a depth of 900 m - 2100 m DBMTS. There is a low density anomaly associated with Coban Hotspring. And layer with a density of 2.4 gr/cm3 - 3.0 gr/cm3 an alleged andesite reservoir, is at a depth of about ≥ 1.5 km DBMT.

Keyword. Arjuno-Welirang, caprock, reservoir, MT and gravity

INTRODUCTION

Arjuno-Welirang is a complex manifold twin volcano stratovolcano with a height of 3,339 m and 3,156 m for Arjuno for Welirang. Arjuno-Welirang complex were two older volcanoes, Gunung Ringgit in the East and in the South Mountain Linting. Geothermal area Mt.Arjuno-Welirang are a Quaternary volcanic rock product that can be separated by the eruption center. Some volcanic products in this area consists of lava and pyroclastic flows [1].

The existence of geothermal Arjuno-Welirang area is characterized by the presence of hot springs (Padusan, Coban and Cangar), precipitated silica sinter around hot springs, and the alteration in the peak of Mount Welirang Shoulders and fumaroles [1].

Geothermal system is a heat transfer system is naturally in a certain volume in the Earth's crust where the heat is transferred from the heat source to the discharge zone [2]. There are four essential elements constituent geothermal system, the heat source, geothermal fluid, reservoir rocks and the covering (caprock), in which the physical properties of each element can be delineated by geophysical methods.

This research will be interpreted Caprock and reservoir models Arjuno-Welirang northern part of the 2D modeling of magnetotelluric (MT) and 3D gravity modeling.

METHOD

MT METHOD

Magnetotelluric (MT) is a passive exploration technique that utilizes a wide spectrum of geomagnetic variation that occurs naturally is lacking as a source for electromagnetic induction in the earth. MT contrast to active geoelectric technique in which the source current is injected into the soil [3].

Magnetotelluric method (MT) is the electromagnetic sounding method (EM) by measuring the passive component of the electric field (E) and the natural magnetic field (H) which changes with time. Comparison between the electric field with the magnetic field perpendicular called impedance which is a medium electrical properties such as conductivity and resistivity. Sounding curves generated from the MT method is apparent resistivity curve that describes the variation of the frequency of the electrical conductivity with depth.

Magnetotelluric method utilizing variations of the electromagnetic field (EM) nature with a very wide frequency of between 10^{-5} Hz – 10^{4} Hz. With a wide frequency range, this method can be used for subsurface investigations of the depth of a few tens of meters to thousands of meters below the earth's surface. The lower frequency is selected it will be more in the range of penetration. While the higher frequency is selected it will be more shallow penetration range. The ratio between the electric field and magnetic field will provide information below the surface conductivity. Ratio at high frequency span shallow subsurface information, while the ratio of the low frequency span in the subsurface information. The ratio can be represented as MT-apparent resistivity and phase as a function of frequency.

GRAVITY METODE

Gravity method is used to describe the shape /structure of the subsurface geology by Earth's gravity field variations arising from differences in rock density. This method can be used to delineate the geothermal prospects for geothermal system that is composed of the covering rock, reservoir, and bedrock have different density contrast. A material / mass heat sources such as rocks in the earth's crust will cause disturbances in the gravitational field that became known as the gravity anomaly.

In the modeling stage, at the gravity data inversion or forward modeling to get a picture of the subsurface structure based on density distribution of the rock. Technically modeling is done using 3D object models shaped prism. When a mass of any 3-dimensional shape is continuously distributed with density, gravity potential at the point P (x, y, x) outside the density distribution is given by [4]:

$$U(x,y,z)=K\iiint\frac{\Delta\rho(\alpha,\beta,\gamma)}{\left[(x-\alpha)^2+(y-\beta)^2+(z-\gamma)^2\right]^{1/2}}d\alpha.d\beta.d\gamma \quad (1)$$

Vertical component of gravity due to mass density distribution obtained by diferensiation equation (1) with z:

$$\Delta g_z(x,y,z)=-\frac{\partial U(x,y,z)}{\partial z}$$
$$=-K\int_0^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\frac{\Delta\rho(\alpha,\beta,\gamma)(z-\gamma)}{\left[(x-\alpha)^2+(y-\beta)^2+(z-\gamma)^2\right]^{3/2}}d\alpha.d\beta.d\gamma \quad (2)$$

RESULT AND DISCUSSION

RESISTIVY ANOMALY FROM MT

Magnetotelluric sounding data is data that shows the relationship between the frequency of the signal with pseudo resistivity. In the data processing phase of MT-Editor looks a cross section of the curve resistivity (ρxy and ρyx). The two curves derived from the value of the impedance (Zxy and Zyx). In response modeling magnetotelluric, electromagnetic fields used plane wave electric field is the polarization field (Transfer Electrical/TE) polarization and magnetic field (Magnetic Transfer / CE). Used so that the curve is resistivity value of Transfer Electric (TE) and Magnetic Transfer (TM) is (ρxy and ρyx). The two resistivity values are sometimes different for each frequency, this is caused by the phase difference of the waves.

Resitivitas used to obtain cross-sectional structure of the subsurface resistivity values result is invariant. Invariant is defined as the main component of the tensor impedance equipment. In other words, the value of resistivity in the subsurface structure of the cross section is the average value of the curve resitivitas (ρxy and ρyx) in the processing stage MT editors (Figure 1).

On geothermal systems in volcanic areas, rock unalterable (caprock) generally give low resistivity response value, while the rock that serve as a reservoir responds resistivity value is higher than the covering rocks [5]. At the study site contained hydrothermal alteration zones or changes. Hydrothermal alteration is due to the difference between the primary minerals with new environmental conditions. In addition to changes in mineralogical constituent rocks, hydrothermal alteration will also change the chemical and physical properties of rocks (eg, density, magnetic properties, and resisitivitas rock).

Based on 2D modeling results in Figure 1 with the regional geology and geothermal Mt.Arjuno-Welirang, then the value of resistivity rocks (Anderson et al. 2000) 2D MT modeling results can be interpreted as follows: a layer of rock with resistivity values (approximately ≤ ± 10 Ohm . m) has a curved pattern in which the sides are thicker than the middle part (orange-red color) is associated with a layer of basalt lava rock consisting of clay minerals result of secondary alteration (alteration) due to fluid interaction with rocks that is passed. Secondary clay minerals that form the covering layer in this research area is mineral montmorillonite Fulida caused by the influence of heat on the area around Mount Shoulders change, so that this layer is thought to

Caprock (overburden) is impermeable. Impermeable area is also affected by faults trending Northwest-Southeast namely Fault Pecan and control the appearance of the manifestation PadusanHotspring.

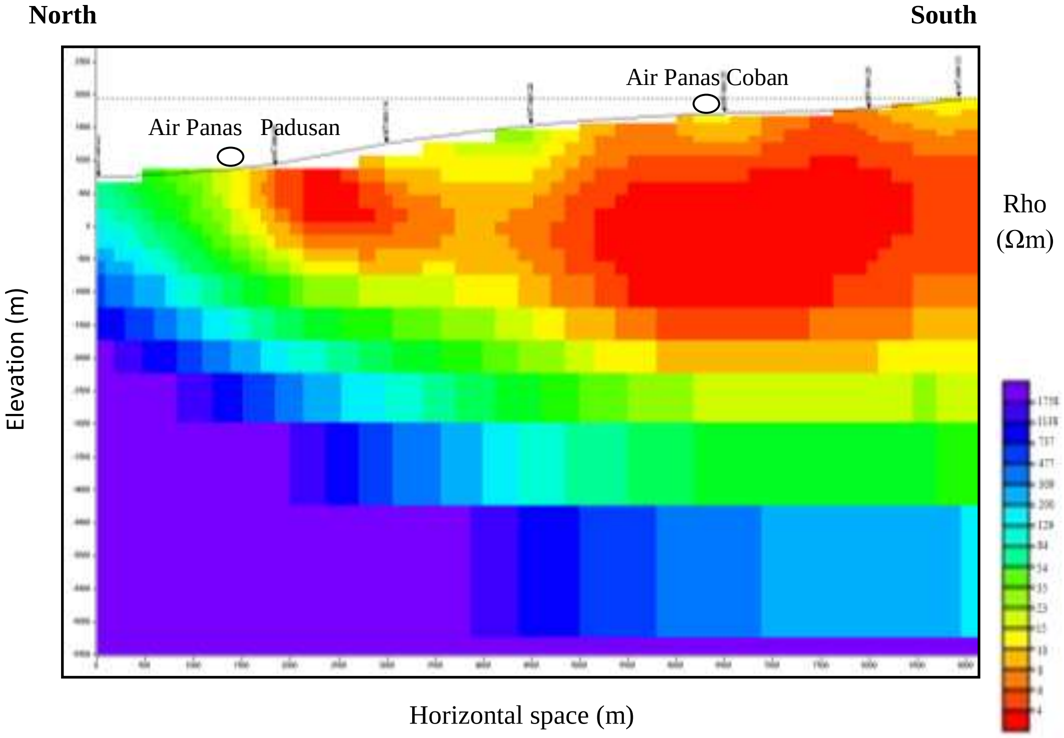

Figure 1. 2D resistivity cross-section result inverse of MT data

Caprock geothermal system has a low resistivity due to the presence of some minerals as the result of hydrothermal alteration of clay minerals, especially the secondary. Overburden has a very important meaning in the overburden rock geothermal system because it will prevent the accumulation of hot water or steam that is formed seeps to the surface quickly so that the rock overburden must be watertight. The overburden is a conductive zone.

Rock layer with resistivity values between ± 10-60 Ohm.m (yellow to green) are likely associated with the age andesite rock bottom quarter is expected to be a reservoir for geothermal systems in the outflow area at the point until MTAW MTAW-08-25. For reservoir formation in this area is influenced by the manifestation Hot Padusan, which contains high concentrations of Cl in the chemical analysis of water so diindikansi any direct connection with the reservoir and permeable zones controlled by Fault Fault Puncung Pecan and that is the pattern of manifestation kemenerusan Coban Hotspring.

BOUGUER ANOMALY

Bouguer anomaly is basically reduced the magnitude of the deviation value Bouguer from Bouguer theoretical value. Complete Bouguer anomaly gravity values that are already in correction; tides, correction of drift, latitude correction, free air correction, Bouguer correction and terrain correction.

Complete Bouguer anomaly to density 2,67 gr/cm3 Mt.Arjuno Welirang geothermal areas are shown in Figure 2. Bouguer anomaly values variation varies from 4-52 mGal with purple to red color scale. Bouguer anomaly values are (28-40 mGal) dominant in the center to the West, while on the North side of the anomaly is relatively lower (25-28 mGal). In the east, a low anomaly (<25 mGal) and the highest anomalies (> 43 mGal) located on the South.

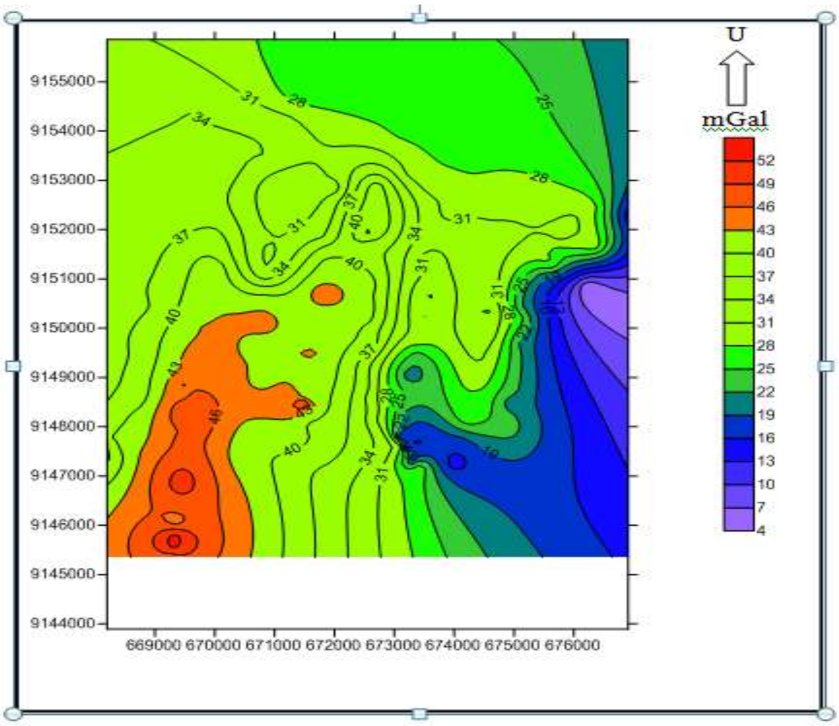

Figure 2. Complete Bouguer Anomaly of Arjuno-Welirang North part

The relative distribution of Bouguer anomaly reflects the geological structure of the rock surface is dominated by andesitic lava Volcano Arjuno-Welirang products. Relatively low in the northern anomaly (25-28 mGal) allegedly associated with pyroclastic flows derived from complex Mt.Arjuno-Welirang (Qapw and Qapaw). On the South by the high anomaly of> 43 mGal Mount Anjasmoro relating to products that are on the West side with andesitic-basaltic lava composition and old lava scattered Welirang Arjuno-West section up Belatan with andesitic-basaltic lava composition. At the height anomalies are Coban Hotspring. For 28-40 mGal anomaly is thought to relate to the Lava Welirang I spread toward the center of the North with the composition of basalt lava.

MODEL 3D ARJUNO-WELIRANG BAGIAN UTARA

Quantitative interpretation in the study conducted by 3D inversion modeling of a complete Bouguer anomaly. 3D modeling is the process of making topographic map models of the subsurface density distribution by showing surface topography, so the model is closer to the real situation. The results of a 3D inversion model of the subsurface density distribution with density display prices on 3D models based Complete Bouguer anomaly indicated by the color contrast from low to high is shown by the red color spectrum to blue (as shown in Figure 3).

From the subsurface density distribution model can be seen that there is a subsurface geological structure layer pattern (Figure 3) is characterized by color changes between red, green and blue indicate rock bedding. The first layer (red) which has a high density, the second layer (green) has a medium density and the third layer (blue) has a small density with a thin layer.

Based on Figure 3 the density values of 1.49 gr/cm3 Caprock - 2.4 gr/cm3 located at a depth of 900 m up to 2100 m DBMTS with the type of material that is clay (clay) and the reservoir is at density 2.4 gr/cm3 - 3.0 gr/cm3 is at a depth of about ≥ 1.5 km DBMTS with rock type is andesite material.

Models pieces under Hotspring Coban shown in Figure 4. Model of low density (blue) associated with the presence of hot springs. This hot break through weak zones or fault structure.

Based on Figure 1, 2, 3, 4 and Nidya geochemical analysis [6] of the surface manifestations of hot water in the North-Welirang Mt.Arjuno over an outflow of geothermal system Arjuno-Welirang. Nidya [6] interpret that type of hydrothermal fluid bicarbonate is water flowing towards the North, where the system is still influenced by surface water that condensed and formed in marginal areas or near the surface. For the reservoir temperature at the outflow area ranging from 145°C - 175°C with the constituent rocks from Quaternary andesite.

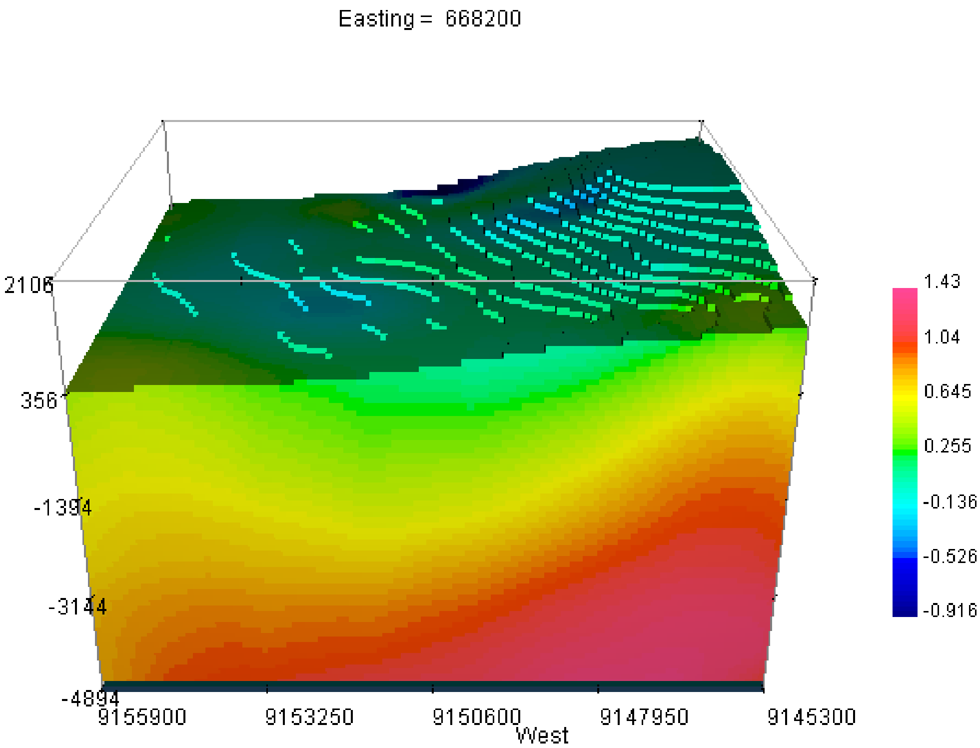

Figure 3. 3D density Model result from Complete Bouguer Anomaly inversion

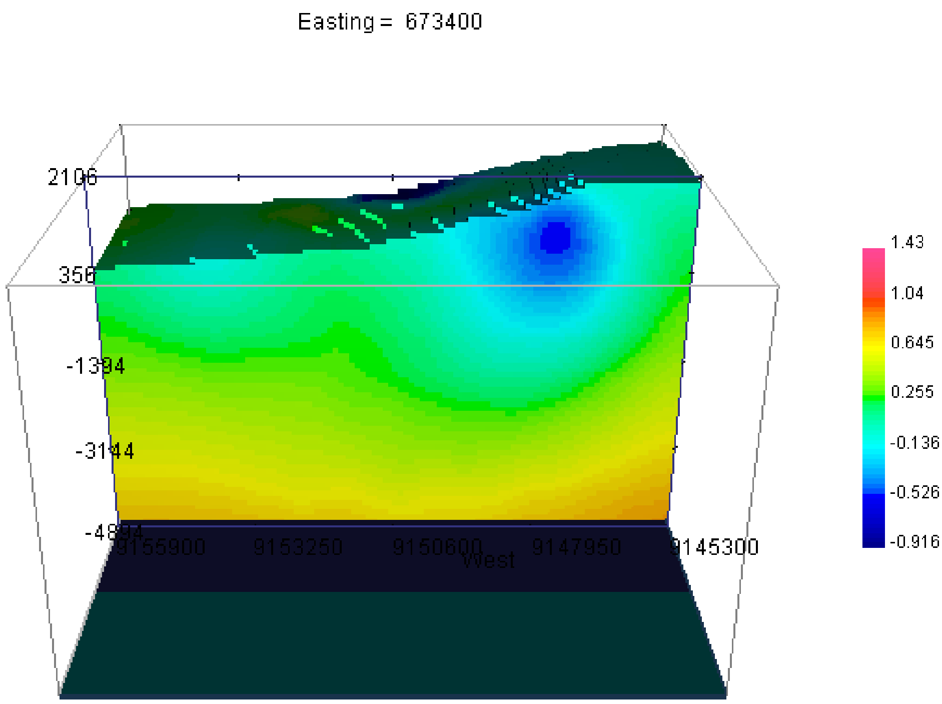

Figure 4. 3D density Model crossing Coban Hotspring

Geothermal reservoir system is characterized by resistivity values ranging from ± 10-60 Ohm.m and density values gr/cm3 2.4 - 3.0 gr/cm3. Reservoir layer there is a layer above the covering (Caprock) are impermeable to the value of resistivity of about ≤ ± 10 Ohm.m and gr/cm3 density values around 1.49 - 2.4 gr/cm3 with basalt lava rock lithology with secondary clay minerals are montmorillonite. Outflow area is controlled by two faults, namely Fault Puncung (north - south) and Fault Klaket (NW - SE). To control the appearance of Fault Puncung Hot Padusan and influence on the formation of an impermeable zone while Klaket Fault is a pattern of straightness and Cangar and Coban Hotspring. Alteration to the area is at the lower layers of manifestation fumaroles located in Mount Welirang and permeable zone (reservoir) is located at the Old Lava lithology Arjuno-Welirang. For the heat source (heat source) on location-Welirang Mt.Arjuno is likely to be on the West to the East.

CONCLUSION

From the analysis of physical properties (resistivity and density values) on the results of the 2D MT inversion modeling and 3D gravity inversion shows that:

a. Caprock geothermal Zone indicated by low resistivity values (≤ ± 10 Ohm.m) and density values around 1.49 gr/cm3 - 2.4 gr/cm3 the distribution patterns of the West to the East. Type of material composed of basalt lava with secondary clay mineral components to be controlled by Fault Puncung.
b. Reservoir geothermal Zone indicated by resistivity medium (± 10-60 Ohm.m) and density values of about 2.4 gr/cm3 - 2.67 gr/cm3 with a depth of about ≥ 1.5 km DBMTS with rock type andesitic lava the age of rocks Quarters below.

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