

A Geophysical Characteristic Over Kelud Caldera Post November 2007 Eruption

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Keywords: Kelud, lava dome, resistivity and magnetic model.

ABSTRACT

VLF and a ground magnetic survey were carried out over the Kelud Caldera, East Java in January 2009. The new lava dome emerged in the November 2007 eruption and filled the western part of the previous caldera. The survey lines are located at the eastern part of this new dome. Preliminary results show that the top layer has higher resistive properties than the lower layer. The resistivity and magnetic model shows that the boundaries of those layers are dipping to the east. According to our interpretation this boundary is related to the flank of the emerged dome.

1. INTRODUCTION

Kelud is stratovolcano in East Java and is still active. The volcano consists of andesite and pyroclastic rock. The morphology of the peak is strongly undulated and steep and made from a lava plug. Eruptions in Kelud before 2007 were explosive. But in 2007, the eruption was effusive. This change made a new phenomenon, a new lava dome in a lake of an old lava dome that appeared on the surface.

If an explosive eruption will burst the new lava dome, it may cause a lot of deaths and damage, because of the village in that area. After the eruption in 2007, mapping of the new lava dome was needed to estimate the amount of debris that might be thrown by the explosion. Old rocks and new lava domes have different resistivity and susceptibility value, so AMT, VLF-R and magnetic methods can used to map the new lava dome.

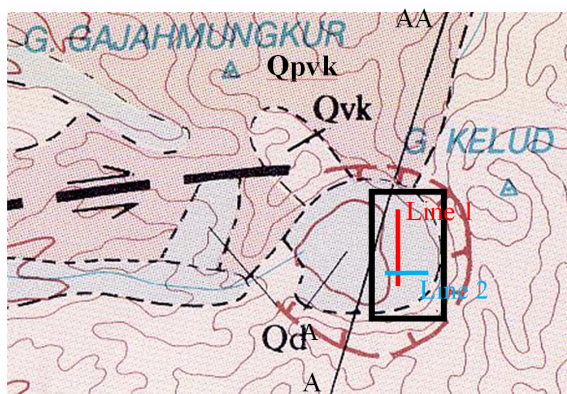


Figure 1: Geological map of Kelud Volcano (Santosa and Atmawinata, 1992).

2. METHODS AND RESULT

2.1 Geology of Kelud

The study area is in the black square in Figure 1. From Figure 1 we can see that this area consist of Kelud debris (Qd), Young Kelud Volcanics (Qvk), and Old Kelud

Volcanics (Qpvk). Old Kelud Volcanic consist of lava, volcanic breccias, tuff breccias, tuff, and lahars from Late Pleistocene. Above this layer is Holocene Young Kelud Volcanics (lava, tuff breccias, agglomerate, tuff and lahars).

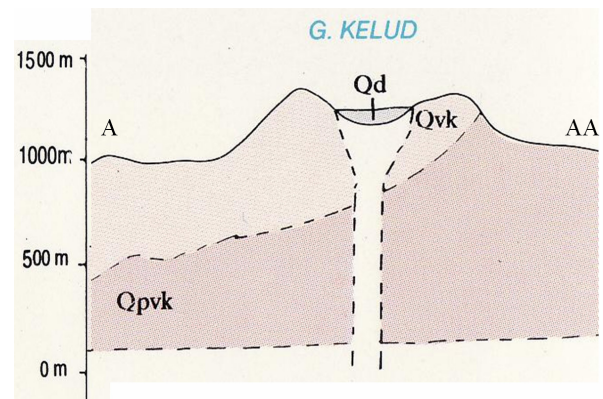


Figure 2: Cross section A-AA of Geological map of Kelud Volcano (Figure 1) (Santosa and Atmawinata, 1992).

The new lava dome after the eruption in 2007 has the estimated cross section in Figure 3.

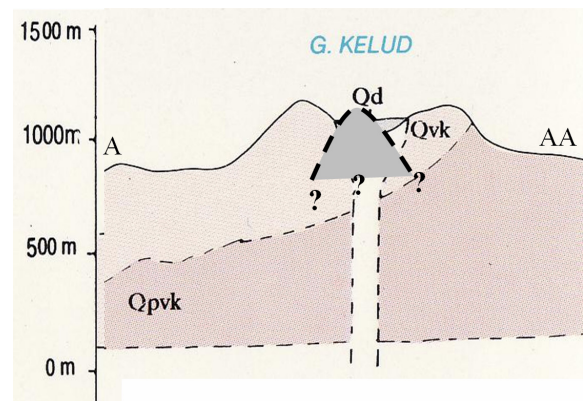


Figure 3: Estimation Cross section A-AA of Geological map of Kelud Volcano.

2.2 VLF-R, AMT and Magnetic Methods

The VLF method uses powerful remote radio transmitters set up in different parts of the world for military communications. In radio communications terminology, VLF means very low frequency, about 15 to 25 kHz. In this study we use 19800 Hz. One unique aspect of VLF surveying is that horizontal electric fields in the ground can be measured using capacitively coupled electrodes. This means that the apparent resistivity can be estimated using H_x , the horizontal magnetic field measured in one direction and E_y , the electric field in the ground measured in the perpendicular direction. The relation for resistivity, ρ , is

described in the following equation, where, ω is angular frequency and μ is magnetic permeability (usually μ_0):

$$\rho = \frac{1}{\omega\mu} \left| \frac{\mathbf{E}_x}{\mathbf{H}_y} \right|^2$$

MT provides resistivity as a new parameter and yields information at depths previously unresolved by potential field geophysics. Interpretation of MT gives resistivities and depths, not just anomalous highs and lows in the data. Therefore, depth interpretation based on MT data is much more definitive than that based on gravity or magnetic data (Vozoff, 1972). The impedance tensor relates electric-field measurements to magnetic-field measurements. Assuming a 1D earth, apparent resistivity, ρ_a , for layered earth is given by:

$$\rho = \frac{1}{\omega\mu} \left| \frac{\mathbf{E}_x}{\mathbf{H}_y} \right|^2$$

Magnetic Methods are used to locate ferrous objects. Total field magnetometers measure the total magnetic field at a given location. Since the Earth's magnetic field changes slowly over short distances, any changes in the measured total field are associated with local targets. The intensity of the earth's field changes depending on your location but typically varies from 25,000 nT to 70,000 nT. The magnetic field intensity associated with a target depends on the size and shape of the target as well as the distance and orientation with respect to the magnetometer, but is usually small compared to the earth's field, and is on the order of tens or hundreds of nanoTeslas. Most materials except for permanent magnets, exhibit an induced magnetic field due to the behavior of the material when the material is in a strong field such as the Earth's. Induced magnetization (sometimes called magnetic polarization) refers to the action of the field on the material wherein the ambient field is enhanced causing the material itself to act as a magnet. The field caused by such a material is directly proportional to the intensity of the ambient field and to the ability of the material to enhance the local field – a property called magnetic susceptibility. The induced magnetization is equal to the product of the volumetric magnetic susceptibility and the inducing field of the Earth (Telford et al, 1990):

$$I = kF$$

where:

k = volumetric magnetic susceptibility (unitless),

I = induced magnetization per unit volume,

F = field intensity in tesla (T).

2.3 Result of VLF-R, AMT and Magnetic Methods

Figure 1 shows the line of our 2 lines. They are located inside of the crater rim. We used a tensor AMT system manufactured by Geometrics. The frequency range was from 10,000 Hz to 1 Hz. We measured two horizontal magnetic fields and two horizontal electric fields. There were no vertical magnetic field measurements. The typical dipole length was 10 m. We used the one-dimensional inversion code of Bostick (1977).

The simplified resistivity model is illustrated in Figure 4. Surface conductive layers indicate the old lava dome, which becomes less significant beneath the crater and the resistive layers below the conductive layers imply the new lava dome. These resistors correspond to layers with the strong magnetization inferred from magnetic survey.

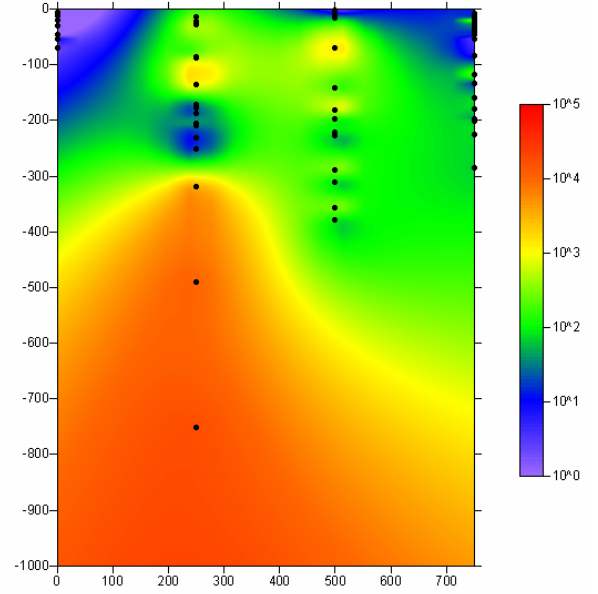


Figure 4: The simplified resistivity model from AMT modeling.

From three methods we can see the subsurface in line 1 (the red line) in Figure 5 and subsurface in line 2 (the blue line) in Figure 6. Figures 5 and 6 are a combination of resistivity and magnetic anomaly, and the anomaly is the new lava dome. The new lava dome gives higher resistivity and lower susceptibility value than the old lava dome.

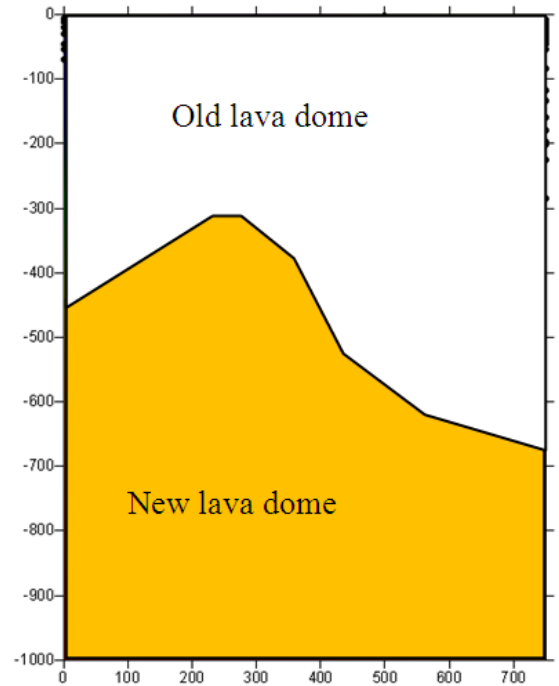


Figure 5: Subsurface from line 1 result.

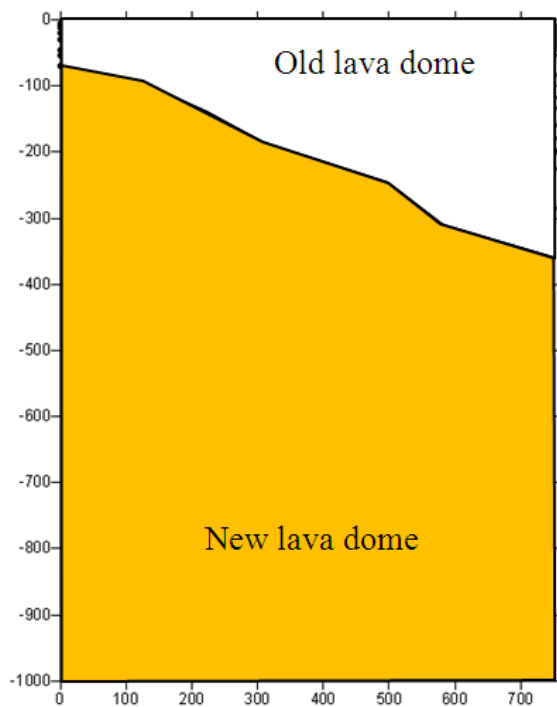


Figure 6: Subsurface from line 2 result.

3. CONCLUSION

The AMT, magnetic and VLF-R methods, applied to the Kelud volcano, enabled us to determine the structure of the first kilometers of the summit area, which in electrical and magnetic terms can be divided into two ranges of resistivity and susceptibility values: a low resistive and low susceptibility, 200 to 400 m thick surface layer, which is characteristic of dry basaltic rocks and mainly constituted by lava flows and tuff breccias that we called old lava dome; and Ž3. a highly resistive and low susceptibility layer, which can be related to the New lava dome.

The major purpose of this survey is to define the location of the new lava dome of the Kelud volcano. It appears to be bounded within the caldera. Less resistive zones at the shallowest depths of this conductive layer are well correlated with the high susceptibility, and can be assumed to be generated by the same source, i.e. the old lava dome. On the contrary, the high resistive ($>1000 \Omega\text{m}$) and low susceptibility layer is assumed to be the new lava dome.

The new lava dome is above the old lava dome and plugs the magma pipe with more than 1000 m depth. Since we cannot separate the resistivity and susceptibility of new lava dome and old lava dome at over 500 m depth, more study with other method is needed to determine the depth of the new lava dome. If the plug (new lava dome) is more than 1000 m, the masses that may be thrown if Kelud explodes will be more than 10^6 m^3 .

ACKNOWLEDGEMENTS

Thanks to Nukman and Wiwit for constructive criticism and help in improving the manuscript. Without Khaerul and “Le Groupe Fort”, this survey would not have been successful.

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