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Geo-electrical and geological strikes of the Mount Lamongan geothermal area, East Java, Indonesia – preliminary results

L R Nugraheni[1], S W Niasari[2] and M Nukman[2]

[1]Undergraduate Program of Geophysics, Universitas Gadjah Mada, Yogyakarta, Indonesia 55281
[2]Geophysics sub-Department, Universitas Gadjah Mada, Yogyakarta, Indonesia 55281

Email: nugrahenirita@gmail.com

Abstract. Geothermal manifestations located in the Tiris, Mount Lamongan, Probolinggo, consist of warm springs. These warm springs have temperature from 35° until 45°C. Tiris fault has NW-SE dominant orientation, similar to some lineaments of maars and cinder cones around Mount Lamongan. The Mount Lamongan geothermal area is situated between Bromo and Argapura volcanoes. This study aims to map the geo-electrical and geological strikes in the study area. Phase tensor analysis has been performed in this study to determine geo-electrical strike of study area. Geological field campaign has been conducted to measure geological strikes. Then, orientation of geo-electrical strike was compared to geological strike. The result presents that the regional geological strike of study area is NW-SE while the orientation of geo-electrical strike is N-S.

1. Introduction

Mount Lamongan is a unique basaltic stratovolcano at East Java, Indonesia. Lamongan Volcanic Field is surrounded by 61 basaltic cinders, 29 prehistoric maars, 2 prehistoric vents, and 1 active vent [1] (see figure 1). This mountain is situated between Bromo volcano to the west and Argapura volcano to the east. Mount Lamongan belongs to volcanic belt zone as a result of subduction between the Indo-Australian Oceanic Plate and the Eurasian Continental Plate.

Warm springs as an indication of a geothermal system and geological structures as one component of a geothermal system are found in the Tiris. Warm springs temperatures range between 35 and 45°C [2]. The orientation of Tiris fault is NW-SE similar to some maars and cinder cones lineaments [3].

Position of Mount Lamongan geothermal system is still debated whether Mount Lamongan has independent geothermal system or a part of the Argapura geothermal system. Several geothermal researches have been conducted at Mount Lamongan to solve this problem. Geochemical evaluation of the geothermal potential of the Lamongan Volcanic Field was investigated [4]. Distribution of ground temperature at Mount Lamongan was analyzed with remote sensing [5]. The result shows that north side Mount Lamongan have ground temperature distribution which generated by geothermal potential Mount Lamongan [5].

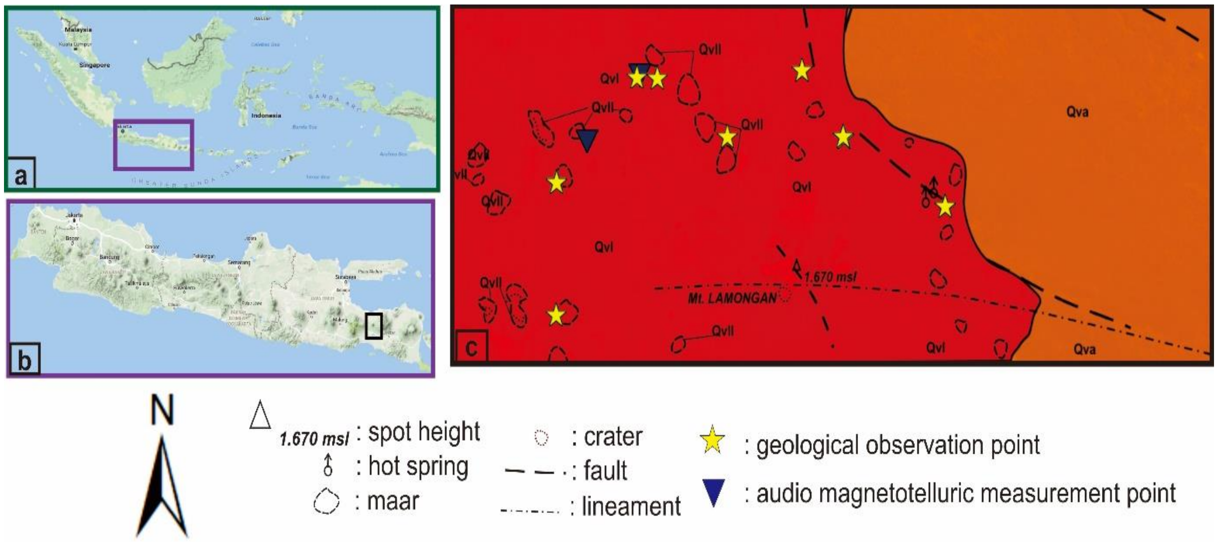


Figure 1. (a) The Indonesian map. Area in purple rectangle is Java Island. (b) The Java Island map. Area in black rectangle is study area. Study area located on volcanic belt zone. (c) Geological map of study area with 2 audio magnetotelluric measurement points (blue rectangles) and 8 geological observation points (yellow stars). Dominant lithology of study area is volcanic rocks from Mount Lamongan consist of Qvl and Qvll (red color) and small part from Mount Argapura consists of Qva (orange color) (modified from [6]).

2. Materials and Methods

Magnetotelluric (MT) is a passive electromagnetic method utilize fluctuation of natural electric (**E)** and horizontal magnetic fields **(H)** in orthogonal directions for determining resistivity structure of the Earth [7]. This method involves the comparison of the horizontal components of the magnetic and electric fields associated with the flow of telluric currents [8]. Element correlates **E** and **H** in frequency domain is impedance tensor (**Z)** [9]. It also reflects the conductivity distribution in some volume below the measurement point [10]. Impedance tensor consists of diagonal (Z_{xx} and Z_{yy}) and off-diagonal components (Z_{xy} and Z_{yx}). Correlation **E** and **H** can be written in matrix form.

$$\mathbf{E} = \mathbf{Z}\,\mathbf{H} \tag{1}$$

$$\begin{bmatrix} E_x \\ E_y \end{bmatrix} = \begin{bmatrix} Z_{xx} & Z_{xy} \\ Z_{yx} & Z_{yy} \end{bmatrix} \begin{bmatrix} H_x \\ H_y \end{bmatrix} \tag{2}$$

Magnetotelluric signals are generated from two sources. Sources from low frequency (less than 1 Hz) are generated from interaction of the solar wind with earth's magnetic field. Meanwhile sources from high frequency (greater than 1 Hz) are generated by thunderstorm activity [11].

Penetration estimate of electromagnetic waves can be determined crudely by skin depth (δ). In electromagnetic, skin depth refers to specific depth where the amplitude of the EM wave reduces to 1/e of its initial amplitude at the surface [12].

$$\delta \approx 503\sqrt{\frac{\rho}{f}} \tag{3}$$

Where ρ is resistivity (ohm.m) and f is frequency (Hz).

Galvanic distortion is one of the key problems in magnetotelluric [13]. It can distort the regional MT responses. Information of conductivity variations at depth is contained in the phase and shape of the amplitude response as a function of the period. Since phase response is free of the galvanic distortions, it can be used to visualize variations of magnetotelluric data at depth without distortion from local heterogeneities. Phase response or phase tensor (ϕ) is ratio of impedance tensor real (X) and imaginary (Y) parts [14].

$$\phi = X^{-1}Y \quad (4)$$

Phase tensor can be represented graphically in ellipse. Major and minor axes of ellipse depict the principal axes and values of the orientation of the major axes specified by the angle ($\alpha - \beta$). α expresses tensor's dependence on the coordinate system. β or skew angle can be thought of as a rotation and is a measure of tensor's asymmetry [14]. The ellipse axis direction is the electrical strike in 2D data [15]. Information of magnetotelluric data can be defined completely in phase tensor by variations of three coordinate invariants consist of ϕ_{max} , ϕ_{min} , and β [14-15].

The area of study lies at the Mount Lamongan geothermal area. The Mount Lamongan geothermal area is interesting geothermal volcanic system area because its position lies between complex volcanoes. Orientation of geo-electrical strike from phase tensor analysis was compared to regional geological strike. Information of the geo-electrical strike, geological strike, and dimensionality of magnetotelluric data are important in subsurface modeling process.

3. Results

Geological field campaign results show that dominant orientation of geological strike is NW-SE with majority value is about N165ºE. This result consistent with Carn's research. From Carn's research in Mount Lamongan, some of the maars have NW-SE orientation comparable with the strike of the Tiris fault [3]. The NW-SE strike orientation of geological features in study area may be caused by regional compression N-S from subduction of the Indo-Australia Plate beneath the Eurasia Plate, which also controls the volcanic belt zone in Sunda Arc.

Phase tensor analysis presents that the dimensionality of data from AMT 2 and AMT 4 are two dimensional for frequency higher than 0.1 Hz. 2-D magnetotelluric data refer to resistivity variation occurring to the depth and one of the horizontal axes direction [7]. These data are graphically represented as ellipses with major axis orientation is N-S (N0ºE and N180ºE) (see figure 2). The orientation of major axis shows the geo-electrical strike direction of study area. The geo-electrical strike refers to the direction representing the orientation of electric current flow in the subsurface due to lateral inhomogeneity of electric conductivity on Earth [16].

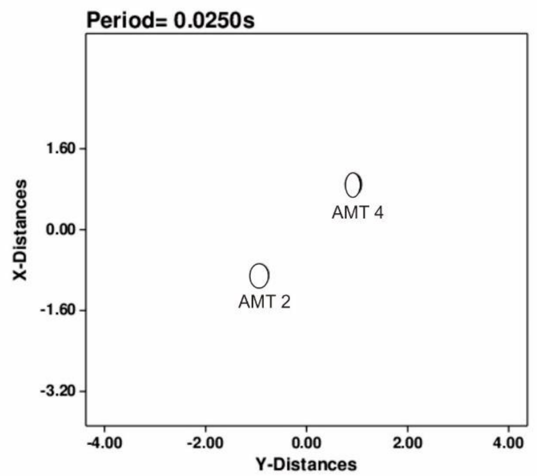
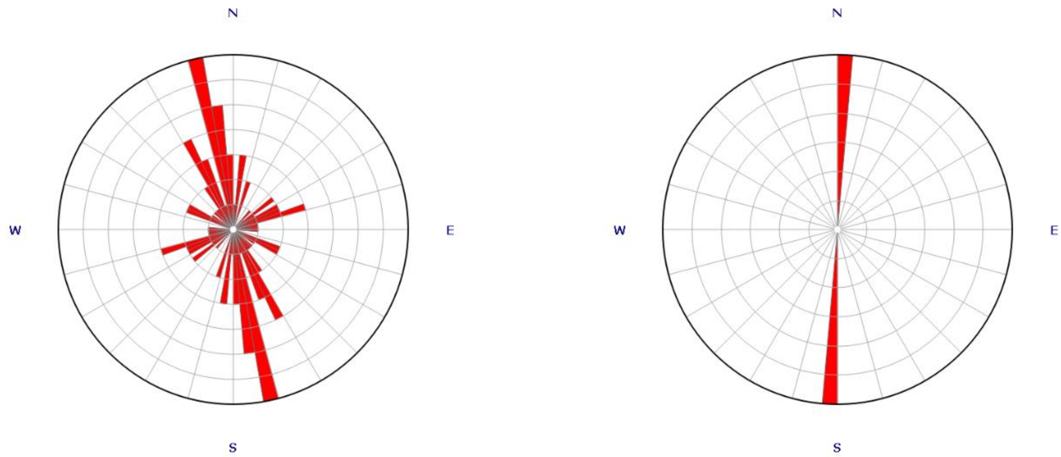


Figure 2. Phase tensor plot from AMT 2 and AMT 4 data in frequency 40 Hz. Dimensionality of data is 2-D. Major axis of ellipse as the geo-electrical strike of area study has orientation N-S.

The results show that orientation of geological and geo-electrical strikes in study area are different (see figure 3). Orientation difference is about 15°. However, the orientation geo-electrical strike still shows the direction of regional compression from N-S, similar with compression which controls the geological strike. This different orientation can be caused by complexity of lithology resistivity and geological structures of study area.



(a) (b)

Figure 3. (a) Rose diagram of geological strikes in study area with NW-SE as dominant orientation. (b) Rose diagram of geo-electrical strikes in study area with N-S as dominant orientation.

4. Conclusion

The orientations geo-electrical and geological strikes of the Mount Lamongan are different. However, their orientations show regional compression from N-S as controller. Information about orientation of geological and geo-electrical strikes in study area are important to get a suitable and accurate model with a minimum error value in subsurface modelling process of magnetotelluric data.

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References

[1] Carn S A 2000 *J. Volcanology and Geothermal Research,* **95** 81-108
[2] Deon F, Moeck I, Scheytt T, Jaya M S 2012 *Geophysical Research Abstracts* **14**
[3] Carn S A 1999 *J. Bull Volcano* **61** 92-105
[4] Deon F, Förster H, Brehme M, Wiegand B, Scheytt T, Moeck I, Jaya M S, Putriatni D J 2015 *J. Geothermal Energy* **3** 1-20
[5] Faridah and Krisbiantoro 2014 *J. Berkala Fisika* **17** 67-72
[6] Suharsono and Suwarti T 1992 *Geological map of the Probolinggo quadrangle, Jawa* (Bandung: Geological Research and Development Centre)
[7] Shimpson F and Karsten B 2005 *Practical magnetotellurics* (Cambridge: Cambridge University Press)

IOP Conf. Series: Journal of Physics: Conf. Series **1011** (2018) 012036 doi:10.1088/1742-6596/1011/1/012036

[8] Cagniard L 1953 *J. Geophysics* **18** 605-635
[9] Vozoff K 1972 *J. Geophys.* **37** 1 98-141
[10] Becken M and Burkhardt H 2004 *J. International. Geophys* **159** 69-82
[11] Naidu G D 2012 *Deep crustal structure of the Son-Narmada-Tapti* (Berlin: Springer) p 14
[12] Khyzhnyak M 2014 *Geoelectric strike and its application in magnetotellurics* (Reykjavik: Háskólaprent) p 6-7
[13] Chave A D and Jones A G 2012 *The magnetotelluric method (theory and practice)* (Cambridge: Cambridge University Press) p 134
[14] Caldwell T G, Bibby H M and Brown C 2004 *J. International. Geophys.* **158** 457-469
[15] Booker J R 2014 *J. Surveys in Geophysics* **35** 1 7-40
[16] Niasari S W 2016 *AIP Conference Pro.* **1755** (Maryland: American Institute of Physics) p 100002