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TEMPORAL ANALYSIS OF VISIBLE-THERMAL INFRARED BAND AND MAGNETOTELLURIC METHOD TO SIMULATE A GEOTHERMAL SITTING AT MT. CIREMAI, WEST JAVA, INDONESIA

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ABSTRACT

Detecting thermal anomaly at surface is crucial for geothermal exploration. Since field observations to map surface manifestation are costly and only limited to certain area, we adopted a temporal analysis of visible to thermal infrared band of Landsat enhanced thematic mapper (ETM+) data. Four scenes data with different acquisition date, but same path and row were used in this study. The purpose of this study is to detect surface manifestation by selecting Mt. Ciremai in West Java, Indonesia. An atmospheric correction is applied to the Landsat ETM+ data to remove the effect of water vapor in the atmosphere. Then, a temporal analysis of NDVI with threshold and Land Surface Temperature (LST) were used to estimate spatially the distribution of surface manifestation. A field temperature measurement at seven locations was used as comparison to the LST. The six zones of thermal anomalous could be extracted by combining the LST with NDVI threshold. Three zones supposed to be related with geothermal system and the others related to human activities. In addition to thermal anomaly detection at surface, a Magnetotelluric (MT) survey was performed at eastern flank of the volcano with the purpose to estimate subsurface structure. Finally, we could find the three suitable zones which has potential for a geothermal sitting at the eastern flanks

INTRODUCTION

The geothermal energy potential in Indonesia is not utilize optimally due to the previous government policy of using fossil fuels predominantly in the last few decades. Indonesia have experienced to produce 1.7 MMBO/day for a few years in 1980’s which now drop into about 0.95 MMBO/day, whereas this condition make Indonesia as net importer oil country since 2002 with additional of about 0.40 MMBO/day. Realizing the recent situation government of Indonesia is planning to generate 10,000 MW electric from coal as well as 10,000 MW electric from geothermal since the last 5 years. In this paper we are discussing mainly on remote sensing analysis and magnetoteluric survey as an exploration activity for Mt. Ciremai area West Java (Figure 1), which is green geothermal area and as a lesson learned to apply in the similar area in order to accelerate the geothermal field development.

Figure 1. Mt. Ciremai Location (Google Earth)

EXPLORATION HISTORY

The initially geothermal information of Mt. Ciremai and adjacent area is collected by volcanology survey of Indonesia and PT. Pertamina based on field survey result which carried out in 1986-1990. Exploration data consists of field surface geological map, geomagnetic, geoelectric, shallow drilling temperature surveys, and geochemical.

There are several surface geothermal manifestation surrounding Mt, Ciremai, consists of fumarol and solfatara in Ciremai crater with 61^{o}C water temperature, hotsprings water cluster ranging from 33-50 ^{o}C. Pertamina is already classifying the manifestation into certain prospect area.

This paper will discuss recent study, which revisited the previous preliminary exploration data and carried out remote sensing approach follow by ground truth with Magnetoteluric survey within certain area adjacent to Mt. Ciremai.

GEOLOGY AND GEOCHEMICAL ASPECT

General Geology

Mt. Ciremai is one of active volcanic with strato type, 3078 m asl height. Morphologically divided into peak morphology which occupied by young volcanic product with 25-40^{o} slope, slope morphology which indicated by parasitic eruption center in the north and southeastern part with 10-25^{o} slope, and toe slope with 5-10^{o} slope, elevation between 100-300 m asl deposited mainly pyroclastics flow product.

The old Ciremai volcanic activity within this area isoriginally by old quaternary which consists of volcanic product of pyroclastics flow and intruded lava of Oligocene-Miocene clastics sediment. The remnant of old volcanic caldera explosion is trending to the north of recent Mt. Ciremai which mostly consists of pyroclastics flow and lava.

Structural Geology

Main geological structure in Mt. Ciremai is almost NW-SE fault which dissected a depression where the young Ciremai volcanic emerged. However, there are also west east fault as a liniament of old Ciremai caldera resulting Sangkanhurip and Pejambon geothermal prospect in the eastern.

Geochemical

D. Erwin Irawan et.al. (2009) carried out recent study for the hydrogeochemistry of Mt. Ciremai and adjacent area. However, recent geochemical analysis which particularly discussing geothermal aspect done by Office of Energy and Mineral Resources,West Java (ESDM, 2010). The results from the recent study confirmed the previous results, which is water from geothermal reservoir mixing from single heat source with meteoric water occurred for most of the hotspring within the geothermal area. The hotsprings have higher Cl content compare with B and Li, which indicated the influence of volcanomagmatic proceses. From silica geothermometer the reservoir temperatureis ranging from 140-180 ^{o}C.

REMOTE SENSING APROACH

Methodology

In the remote sensing analysis for land temperature surface, we use public domain of Landsat imagery from USGS. The first step before data processing is atmospheric correction to reduce wave distortion effect passing space with different density, simple example is if we put wooden stick in the water, it seem bent not straight.

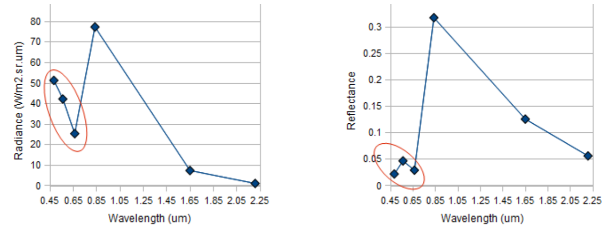

Figure 2. The response of before (left) and after (right) atmospheric correction process to the data. This process automatically transformed the data from radiance to reflectance

In order to reduce ambiguity due to human activity and vegetation is take into account in the processing step. For visible (VIS) until short wave infra red (SWIR) band, the ENVI, FLAASH (fast line of sight atmospheric analysis of spectral hypercubes) correction is applied, which input is digital number (DN) change in to radian. The output from the correction is surface reflectance (Figure 2).

Land Surface Temperature (LST)

The thermal infra red (IR, band 6) correction is applied, as DN transformation to radian and then to LST. Four ETM+ band 6 (10.4-12.5 μm) is applied to calculate LST, every DN pixel from band 6 converted to *top-of-atmospheric* (TOA) radian as shown by formula 1:

$$L_{\alpha} = \frac{L_{max} - L_{min}}{QCAL_{max} - QCAL_{min}} (DN - QCAL_{min}) + L_{min} \quad (1)$$

Where, L_{α} is spectral radiance at TOA in W/m^{2}*sr*μm, $QCAL_{max}$ and $QCAL_{min}$ is maximum pixel value (=255) and minimum(=0), L_{max} and L_{min} is scaled radiance of $QCAL_{max}$ and $QCAL_{min}$, and DN is pixel value in imagery. The conversion objective is deriving radiance value in satellite sensor, since the real target is in earth surface whereas the sensor is in the outer space. Subseqently, atmospheric correction done for each TOA radiance by:

$$L_{T} = \frac{L_{\alpha} - L_{\mu} - \tau(1-\varepsilon)L_{d}}{\tau\varepsilon} \quad (2)$$

Where, L_{T} is radiance of target kinetic blackbody in temperature T (Yuan and Bauer, 2007), L_{α} is spectral radiance at TOA, L_{μ} dan L_{d} is *upwelling* (radiance in atmosphere) and *downwelling* (radiance in outer space), τ is atmosphere transmisivity and ε is target emisivity. The parameter of atmosphere physics of L_{μ}, L_{d}, τ can be derived by radiance transfer modeling software MODTRAN developed by Barsi et al. (2007), the software is available online at http://atmcorr.gsfc.nasa.gov/ while the modeling results is automatically send by email, the ε *parameter derived from* USGS Modis Emissivity Library, 2010. Finally, the corrected TOA radiance from atmospheric effect is converted to LST by:

$$T = \frac{K_1}{\ln\left(\frac{K_2}{L_T} + 1\right)} \qquad (3)$$

Where, T *is* temperature in Kelvin (K). For the technical purpose we converted from K to Celcius (C) by 273 factor. K_1 and K_2 is calibration constant 1 and 2, which taken fromi Chander et al., (2009). L_T is radiance from equation (2). The LST anomaly of A-F results is shown in figure 3

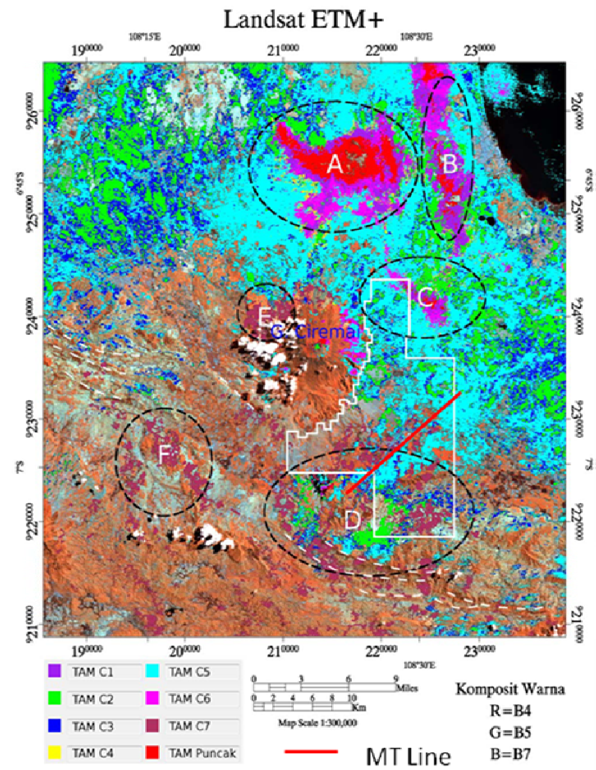

Figure 3: The LST anomaly based on TAM classification with composite color of RGB band 457

The E-F LST anomaly derived without field measurement is coincident structural liniament in the southern part Mt. Ciremai.

MAGNETOTELLURIC (MT) SURVEY

Nowadays, in Indonesia the MT survey is one of compulsory geophysical method to be carried out within geothermal field area, in order to reduced uncertainty and better prognosis for new geothermal exploration well.

Data Acquisition

The MT survey is acquiring electromagnetic (E_x, E_y, H_x dan H_y) time series data of component horizontal field, which meausered at the surface. range frequency from 400 Hz until 0.0000129 Hz or 21.5 hours period. The lower frequency record correlated with deeper subsurface. The MT data contained electric and magnetic field variation, total point acquired in this survey is 10 points.

Interpretation Results

The ESDM, 2010 study of 2-D inversion MT modeling of geology interpretation result is shown in figure 4. The inversion process is reaching 15 times iteration with less than 5% RMS error. The interpretation for the 2-D section is based on layer resistivity values, which varies from less than 100 ohm-m, and more than 1000 ohm-m. Layer 1 is correlated with quaternary product which have high saturated water even within young volcanic product of Mt. Ciremai. Layer 2 with resistivity less than 1000 ohm-m showing deeper aquifer zone and contact due to different rock texture between volcanic product and sediment. Layer 3 is basement rock with more than 1000 ohm-m is related with volcanic rock and altered sediment rock.

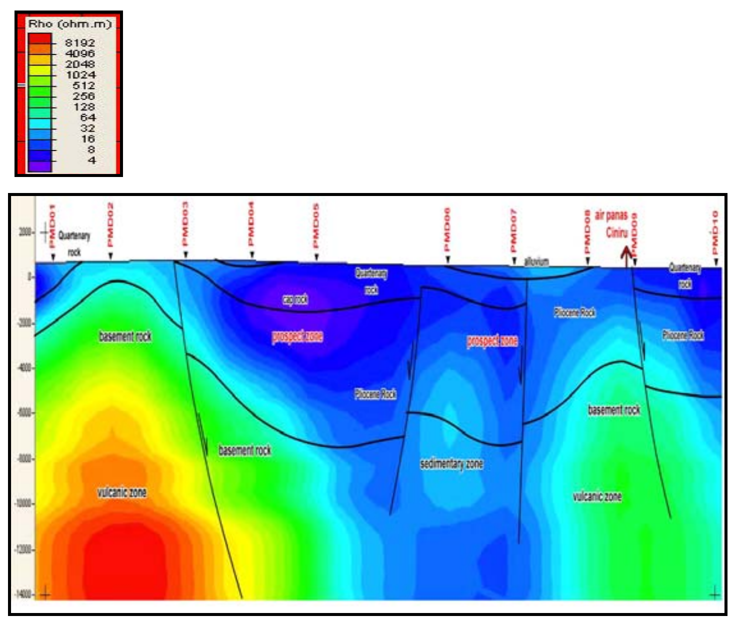

Figure 4: The geology interpretation of MT 2-D with sharp boundary model

CONCLUDING REMARKS

The remote sensing and magnetotelluric results is demonstrating a good data match for revealing subsurface condition within geothermal area. The field survey guided by imagery analysis can support MT survey design and accelerate exploration in to exploitation as well as reducing risk for unsuccessfully drilling target for the geothermal reservoir.

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