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Research Paper

Geothermal Area Analysis in the Mt . Batur Area, Bali, Using Landsat-8 and Gravity G Gm-Plus Satellite Data

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ABSTRACT: *The Batur geothermal area was analyzed using Landsat 8 satellite data and gravity data. Geothermal areas generally correspond to areas with higher temperatures. Geothermal areas also correspond to shallow magma reservoirs. These two-satellite data are expected to be used for preliminary analysis of geothermal areas and other geological structures. Results from LST and Gravity is the Batur geoth that the Batur geothermal area corresponds to the high-temperature area. Based on gravity data, that area is on the high-value local anomaly area t of Mount Batur. Land surface temperature (LST) is 31^{0}C to 43^{0}C and gravity local anomaly is 3 mGal to 6 mGal. The high value of gravity local anomaly corresponds to a magma reservoir associated with geothermal manifestations and changing position of the active crater. The magma reservoir location is predicted in the southwest to northeast.*

KEYWORDS: *Geothermal, Mt. Batur, Lansat-8, Gravity*

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I. INTRODUCTION

A large number of volcanoes in Indonesia are caused by Indonesia's position in the ring of fire. One of the benefits of having volcanoes is geothermal energy sources. Geothermal is renewable energy. Renewable energy is environmentally friendly green energy with minimum pollution and low emissions. The number of geothermal resource locations throughout Indonesia is 265 with a total potential of 28.1 Gwe [1,2]. Most of the geothermal resource locations are associated with volcanic activity and only a small proportion are associated with non-volcanic systems. Volcanic geothermal sources have a larger reservoir than non-volcanic geothermal sources. The geothermal system utilized at this time is of the type of volcanic complex, caldera, and cone-graben [3]. Geothermal utilization for power plants to date is only 1189 MWe or about 4% of the total potential. [4,5]

To explore the abundant geothermal energy in Indonesia in various locations, a study of the initial search method for geothermal areas is carried out by utilizing satellite data. Various satellite data such as gravity, magnetic, atmospheric data, etc. can be accessed free of charge, so that satellite data can be used as an initial estimate of the existence of geothermal energy [6,7].

One of the volcanic geothermal areas is Mount Batur, Bali. The Batur geothermal manifestation area is in the world geopark area (Global Network of National Geoparks) which was declared by UNESCO. The Batur area is a unique geological area consisting of a large caldera and a lake. Batur Caldera consists of old and young Caldera. The area of the Batur caldera is 2300 km2, which leads to the south and has a steep slope, to the north [8]. In the young caldera, there is Mount Batur which is active until now. Mount Batur is surrounded by the walls of the old Batur caldera. Volcanic activity in the past contributed to the formation of Lake Batur formation and. Mount Batur is an active volcano with more than 25 eruptions since 1800. The type of eruption that occurred was a stromboli type, and the location of the youngest crater is to the southwest of the previous craters [9].

Landsat 8 is an earth monitoring satellite that has 2 sensors, an operational land imager (OLI) sensor and a thermal infrared sensor (TRIS). Landsat 8 is used for the identification of land cover, identification of vegetation types, identification of geothermal prospect areas, etc. [10-15]. Identification of geothermal manifestations such as hot springs and rock alteration can be done directly in the field, but it will take a lot of time and money. An indirect method is needed that can provide initial information about geothermal prospect points using satellites. Satellite data that identifies temperatures such as in Landsat 8 can be used to determine location points but must be supported by other data. GGM satellite gravity data has a higher resolution than ICGEM gravity data. For target local anomalies, GGM produces more detailed values for local anomalies [16-18]. The local gravity anomaly can provide an initial model of the subsurface structure in an area. The use of multiple satellite data can help complement the results of the research analysis.

This study uses 2 satellite data, gravity and Landsat 8. The target of using satellite data is mapping geothermal locations based on gravity and surface temperature data in a volcanic area. Current remote sensing technology has high accuracy and also low cost. By using Landsat 8 we can obtain the surface temperature of an area and by using the gravity disturbance data we can obtain the local anomaly value of the suspected geothermal area.

II. METHODS

The research uses gravity disturbance, elevation, and Landsat-8 data. Landsat-8 data uses satellite data downloaded from the official website of the United State Geological Survey (USGS) (https://earthexplorer.usgs.gov/). The gravity disturbance and ERTM data use satellite data downloaded from the Curtin University website. Mt. Batur is a unique volcano in Bali. The position is one line with Mt. Abang and Mt. Agung. A part of Mt. Abang had already collapsed when Mt. Batur erupted a few years ago (Figure. 1). The research uses gravity disturbance, elevation, and Landsat-8 data. Landsat-8 data uses satellite data downloaded from the official website of the United State Geological Survey (USGS) (https://earthexplorer.usgs.gov/). The gravity disturbance and ERTM data use satellite data downloaded from the Curtin University website. Research area boundaries are caldera 1, and caldera 2. With geographical boundaries are 9082000 S to 9096000 S and 310000 E to 330000 E (-8.30^0 to -8.15^0 and 115.25^0 to 115.40^0).

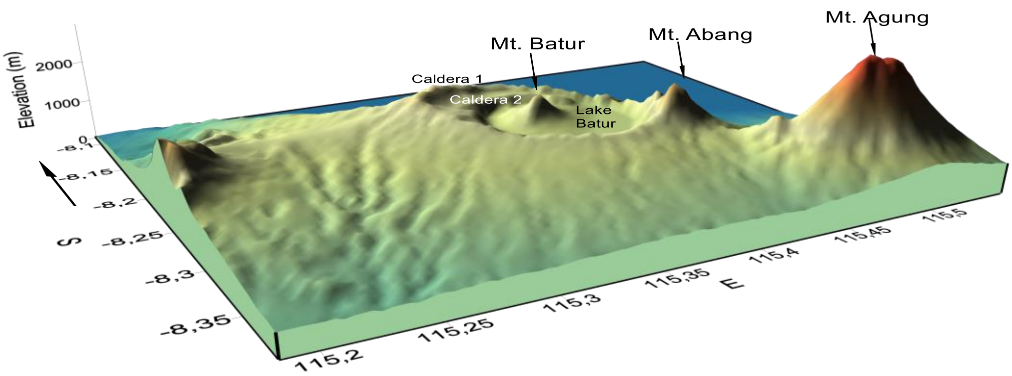

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Figure 1. Mt. Batur, Mt. Abang and Mt. Agung

This study applies corrections to Landsat 8 data and gravity disturbance data to obtain free data from noise. The gravity disturbance is anomaly-free air data, so corrections are made to obtain local and regional anomaly values. The correction process carried out consists of Bouguer and terrain corrections [19,20].

The correction process produces a complete Bouguer anomaly value. Separation of local and regional Bouguer anomalies using the Gaussian method. The local anomaly has been analyzed with LST to find the correlation between local anomaly, geologic feature, and LST.

The correction made in processing Landsat 8 is the radiometric correction. Radiometric correction is performed to obtain initial data that is free from atmospheric disturbances, solar effects, and tool interference. The radiometrically corrected data will be used in the next process which obtains the surface temperature. The temperature that is conducted to the earth's surface is a combination of various heat sources that exist below the surface. Land Surface Temperature (LST) is the outermost temperature on the surface. LST is a remote sensing parameter that is used to determine the manifestation of heat in an area. The accumulation of temperature on the earth's surface will affect the physical properties of objects on it. Physical properties of objects on the surface have influenced emissivity, specific heat capacity, and thermal conductivity. Temperature sensing is carried out by the Landsat 8 OLI/TRIS thermal sensor using infrared. The surface temperature calculation process consists of converting a digital number to spectral radiance, converting spectral radiance to brightness temperature, and converting brightness temperature to surface temperature [15-18]. The three stages are formulated as follows:

$$L_\lambda = M_L Q_{cal} + A_L$$

$$T_B = \frac{K_2}{\ln(\frac{K_1}{L_\lambda}+1)}$$

$$T_s = \frac{T_B}{\left[1+\frac{\lambda T_B}{\partial}\right]\ln(\varepsilon)}$$

L_λ is Spectral Radiance, M_L is a multiplier factor for Landsat 8 specific bands, Q_{cal} is a digital number, A_L, and is an increasing factor in Landsat 8, T_B is the Brightness Temperature (K), K_1 and K_2 are the thermal calibration constants on Landsat 8, T_s is the land surface temperature (K), λ is the wavelength of the radiation (λ = 10.8 m), ∂ is 14388 μm K, and ε is the emissivity.

III. RESULTS AND DISCUSSION

Batur area is at an elevation of 0 m to 2200 m. Mt. Batur is at an elevation of 1100 m to 1500 m, while Lake Batur is at an elevation of 1050 m. The topography around Mount Batur is higher so Mount Batur is located within calderas 1 and 2. Caldera 1 is higher and wider than caldera 2, this illustrates how big the eruption has been before. Ancient Batur is estimated as a very large mountain and bigger than Mount Agung. Young Batur is still active until now. Mount Batur includes Mount Batur old and young. Mount Batur includes the Main Volcano Cone, Mount Abang Parasite Cone, Hill in the Caldera, Sampeanwani Hill, Puraknya Hill Avalanche, Mount Bunbulan Lava Stopper, and various types of Batur Volcano products (Mount Batur lava). An important post-volcanic caldera event is an eruption that produces glassy-textured lava with its constituent compositions ranging from olivine basalt to basaltic andesite erupted from the center of the caldera. There are at least three volcanic cones that have been built during the formation of Mount Batur, with the main crater in a northeast-southwest direction [8,9,21-23].

The results of satellite gravity processing obtained local and regional anomalies which are mapped in Figures 2 and 3. The local anomaly value is -24 mGal to 12 mGal. The peak area of Batur has a local anomaly value of -8 mGal to -4 mGal. The anomaly -24 mGal to -12 mGal is located at Mount Abang and Caldera 1, to the north to the northeast of the peak of Batur. The high anomaly is in the northwest and south of the Batur area. Batur crater that forms the northeast direction is in the high anomaly area. Regional anomaly value 92 mGal to 132 mGal. The Batur area is at a value of 102 mGal to 120 mGal. The contour of the regional anomaly is trending southwest-northeast. The high anomaly in the southeast decreases in value to the northwest by 40 mGal. There was no significant anomaly on the Batur's regional contour. There are high anomaly values that are represented by that color in the southern region in local and regional anomalies. This indicates that the high density in the area is associated with deeper volcanic activity in Batur, Abang, and Agung.

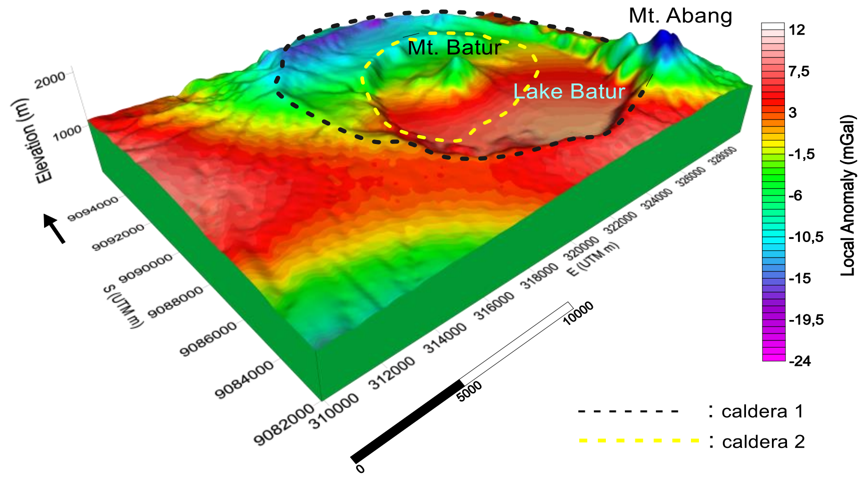

Figure 2. The local anomaly of Mt. Batur on topographic using the Gaussian separation method.

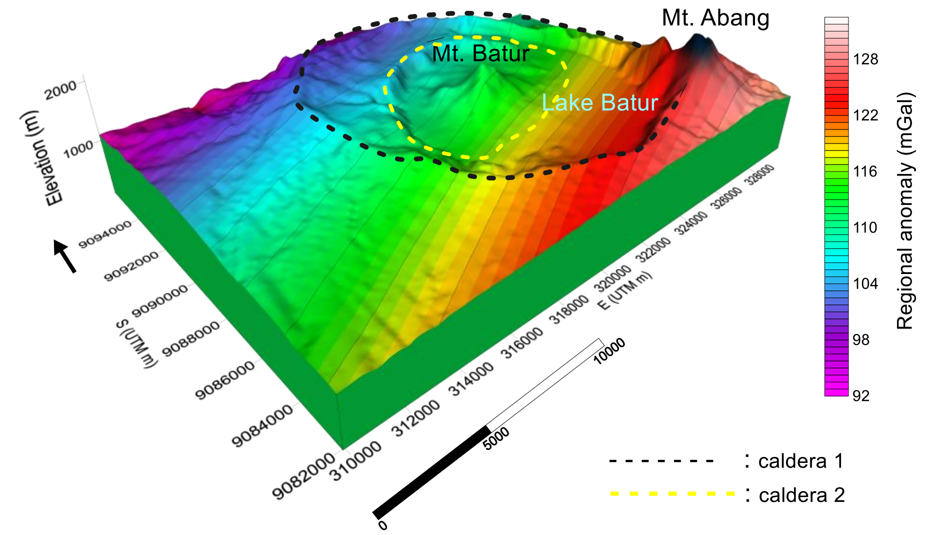

Figure 3. The regional anomaly of Mt. Batur on topographic using Gaussian separation method.

The results of LST processing obtain a surface temperature of 12° C to 43° C, shown in Figure 4. High LST is in the western and southwest areas of Mount Batur, which are marked in red. The high temperature is 37° C to 47° C, while the low temperature is 11° C to 22° C. Low LST is in the southeast and northwest. The old Batur caldera to the young Batur volcano has a surface temperature of 22° C to 43° C and is dominated by a surface temperature of 25° C to 31° C. The peak area of Batur has a temperature of 30⁰ C to 43⁰ C. The active crater area and the former active crater have a higher temperature than the surrounding area.

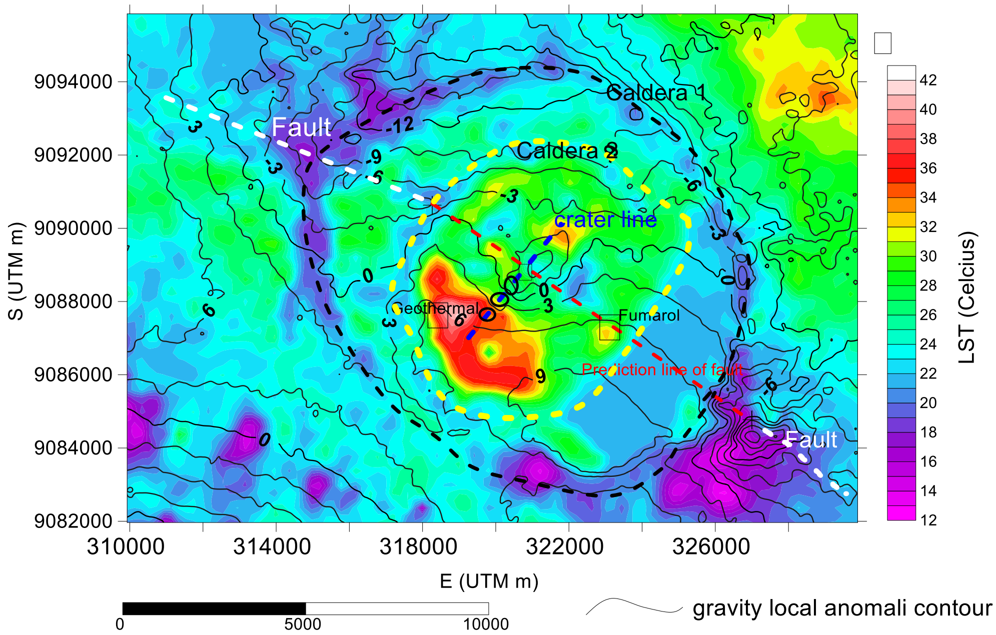

Figure 4. Land Surface Temperature overlay with geological structure and local anomaly of Batur.

Mt. Batur has a characteristic position of the crater which moves and forms a northeast direction. The crater that moves to form a northeast and northwest direction is thought to be related to the fault in the Mount Batur area. The characteristics of Batur eruptions are generally semi-volcanic types that end with stromboli and lava flows. The series of eruptions lasted several months until several craters were formed. Based on historical records, the first eruption of young Batur began in 1804 [9,21-23]. There are 2 manifestations of fumaroles on the shores of Lake Batur. Another manifestation is geothermal based on research from PSDG (Mineral Resources Center) located southwest of Batur, inside caldera 2. The LST results show high-temperature of fumarole and geothermal manifestations. The geothermal area has a higher temperature than the fumarole manifestation area. Fumarole manifestations appear in the southwest and northeast of Mount Batur. Research on terrestrial gravity by PSDG in the Mount Batur area resulted in the identification of fumaroles and ground surface temperature anomalies. The higher surface temperature is thought to be a higher heat than the surroundings due to the presence of faults in the study area. The fault in the study area is thought to have contributed to the formation of geothermal manifestations [24]. The existence of fumaroles near Lake Batur. The fumaroles manifestation research used MT (Magnetotelluric). The research result there is a low resistivity zone near Lake Batur. The low resistivity zone is in-depth at 100 m with a resistivity of 20 Ω m, and a thickness of 200 to 500 m. The high resistivity is 50 Ω m to 200 Ω m with a thickness of 500 m [25].

The geological profile of Batur published by ESDM describes a magma pipe to the south of the top of Batur towards the boundary of caldera 2. In Figure 5, many magma pipes in the area indicate that many gaps below the surface allow lava to reach the surface. In addition, it is estimated that magma deposits exist in the area. The magma pipe forms the southwest-northeast direction.

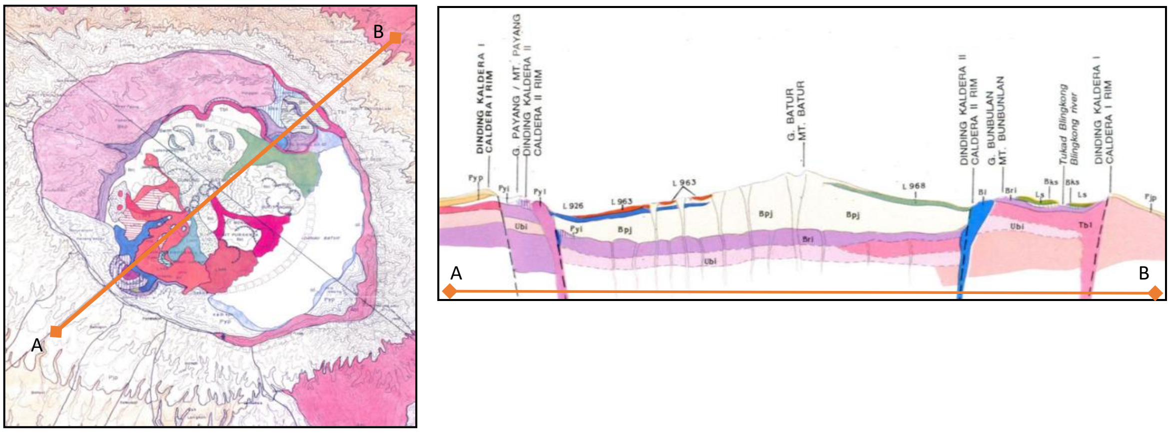

Figure 5. Geological map of Batur produced by ESDM [26]

The magma reservoir associated with geothermal manifestations and changes in the position of the active crater is thought to be in the southwest to northeast. Land surface temperature and gravity can be combined to analyze the area of geothermal manifestation. The Caldera border can be identified by land surface temperature corresponding to the low value of LST. There is no information about the straightness of the Batur fault from northwest to southeast, but the straightness by LST on the peak area can be predicted that the fault is straight to the southeast but turns to the northeast.

IV. CONCLUSION

Based on the land surface temperature, the Batur geothermal area corresponds to the high-temperature area, and based on gravity data that area is on the high-value local anomaly area which is in the southwest of Mount Batur. Land surface temperature (LST) is 31^0C to 43^0C and gravity local anomaly is 3 mGal to 6 mGal. The magma reservoir associated with geothermal manifestations and changes in the position of the active crater is thought to be in the southwest to northeast. Land surface temperature and gravity can be combined to analyze the area of geothermal manifestation. The Caldera border can be identified by land surface temperature corresponding to the low value of LST.

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