Structure Zone Identification as a Geothermal Fluid Path using Gravity Euler Deconvolution-Case Study on Geothermal Area AA

A. Armando¹,²*, Y. Daud¹, and Jatmiko Prio Atmojo²

¹Department of Physics, Master Program of Geothermal Exploration, Faculty of Mathematics and Natural Sciences, University of Indonesia
²Upstream Technology Center, PT Pertamina (Persero)

*E-mail : adilla.armando51@sci.ui.ac.id, adilla.armando@gmail.com

Abstract. An Euler deconvolution technique is one of geophysical method for rapidly making depth of anomaly estimated from gravity. Preliminary results from Euler deconvolution of gravity survey (300 meter spacing station) which analyzing on geothermal prospect area, provide confirmation of a structure zone as a geothermal fluid path, such as fault and fracture. In addition, the data allow identification of the location and trend of contact fault that has not been recognized at the surface (satellite mapping). Contact faults can be interpreted from the Euler deconvolution gravity by using SI of 0.0, while dyke use SI of 1.0 and is represented as the boundary of negative anomaly and positive anomaly on Gravity modelling. The experimental results show that the structure zone distribution of euler deconvolution is localized at a depth of 374 to 579 meters below the surface with a percentage of 59%. Especially, structural zones where are localized near upflow manifestations are at a depth of 374 to 783 meters below the surface, while structural zones where are near outflow manifestations are at a depth of 150 to 570 meters below the surface. This euler deconvolution structures zone are also inline with geology structure.

Keywords: Euler Deconvolution, geophysical method, structure zone

1. Introduction

Geothermal is one of potential renewable energy in Indonesia, which is obtained by extracting some hot fluids from the mature reservoir that is accumulated and heated for millions to milliliters years, eventually stored in a place which be called as reservoir layer. This hot fluid can flow from the reservoir layer, vertically (called upflow flow) or horizontally (called outflow flow) through a flowing path called as geological structure. Vertical flowing is usually dominated by a gas fluid, while the lateral flowing is dominated by liquid fluid (pure/ mixed). An area which is geothermal potential generally has surface signs that are often called surface manifestations. This manifestation may be gaseous (such as fumarole, steaming ground, warm ground) due to the fluid flowing of gas (upflow), and liquid form (like hot springs) due to fluid flowing (called as outflow flowing). In the geothermal system is also required to have a recharge area (water flowing into the ground) as the circulation of renewable systems. This geothermal fluid extraction is converted to electricity, which is called as geothermal power plant.
Indonesia has the largest geothermal potential in the world 29 GWe [2].

The AA geothermal prospect area is located on central Indonesia part. Geological condition of this area is dominated by tertiary and quartz age. The tertiary age formation consist as shale rock and sand rock, intersecting between limestone and fine grained sandstone (chert), and cemented by tertiary-quarter volcanic rocks. The surface manifestations found in this area are fumarol which has a surface temperature of 107 °C, and some hot springs with a surface temperature of 37-75 °C [6]. The appearance of these manifestations is controlled by several geologic structures which is called as fault and caldera formations imaged by satellite mapping (DEM).

Based on DEM mapping results in the area, much geologic structures have regional orientation of NW-SE and NE-SW, indicated as controller the product of surface manifestation and some surrounding alteration areas. The geological structures in this area as the result of volcanic activity interaction which intersecting to cracks/ unconformity layer, especially in the quartz igneous rock and sedimentary basement rock.

In the geothermal system, the existence of the interconnected structure can be hypothesized as the geothermal fluid path [4] and becomes one of considerations whether the area is productive to be drilled or not, in which the permeable zone expecitely can produce large output drilling. In process to mapping the distribution of structures in this area, another proper technique is required that helps to support besides from DEM and field geology study, which is extracting attributes of the Gravity method, ie Euler Deconvolution.

| SI  | Magnetic Field | Gravity Field |
|-----|----------------|---------------|
| 0.0 | Contact        | Sill/dyke/step|
| 0.5 | Thick step     | Ribbon        |
| 1.0 | Sill/dyke      | Pipe          |
| 2.0 | Pipe           | Sphere        |
| 3.0 | Sphere         |               |
2. Literature Review

2.1. Euler Deconvolution Method

The Euler Deconvolution technology is used to determine the lateral and depth geometry of gravity anomalies based on the gradients of the gravitational field (against axis and ordinate parameters) with some constraints [6]. The formula of this equation is

\[
(x - x_0) \left( \frac{\partial G}{\partial x} \right) + (y - y_0) \left( \frac{\partial G}{\partial y} \right) + (z - z_0) \left( \frac{\partial G}{\partial z} \right) = N(B - G)
\]

(1)

Where

- \((x_0, y_0, z_0)\) : Reference point from gravity point \((x, y, z)\)
- \(N\) : Structure Index (SI)
- \(B\) : Regional Gravity Value
- \(G\) : Observe Gravity Value

Zhang et al. [6] proposed this equation for the gravity anomaly vertical component \(T_z\) of a body having a homogeneous gravity field. In equation (1) \(x_0, y_0, z_0\) are the reference position of the source body and \(x, y, z\) are gravity data observation coordinates. The values \(T_x, T_y, T_z\) are the measured gravity gradients along the \(x-, y-, z-\) directions; \(N\) is the structural index; and \(B_z\) is the regional gravity value. Equation (1) can be modified as

\[
x_0 T_x + y_0 T_y + z_0 T_z + NB_z = xT_x + yT_y + zT_z + NT_z
\]

(2)

There are four unknown parameters \((x_0, y_0, z_0, B_z)\) in equation (2). Within a selected window, there are \(n\) data points available to solve the four unknown parameters. When \(n > 4\), these parameters can be estimated using Moore-Penrose in-version (Lawson and Hanson, 1974) or equivalent techniques.

An input value of the index structure describes the type of anomaly should be identified. In the context of this study, I use index 0.0 which interprets that an anomaly described as a fault anomaly correlated with the permeable zone.

2.2. Gravity Data Acquisition Distribution

Total Gravity stations which measured are 222 points and forms 6 grid lines, crossing fumarole in the south and 4 hot springs controlled by regional fault structures. The distance between each station is 100 meters. Gravity data which is the result of acquisition & pre-processing results has format .GRD, where the data is ready to be extracted using Euler Deconvolution method and will be correlated with Geology structure map.

![Figure 3 Gravity stations layout in Geothermal prospect area AA](image-url)
2.3. Structure Distribution Based on Geological Mapping

The geology structure is dominantly direct to the northwest-southeast, northeast-southwest and west-east. Some fractures are identified in this prospect area control to the appearance of hot springs. The fault structure which spreading into the west-eastern direction in sedimentary rocks controls the appearance of the hot springs of Pusian and Bakan. The northwest-southeast trend fault controls the appearance of Lobong hot springs. The appearance of fumaroles and solfatara is also controlled by some faults which is orientated by northeast-southwest.

The Pinasungkulan-Makaroyen Plain is formed by the graben that intersects the old Ambang caldera. The formation of the caldera structure is seen from the ridge range of elongated and circular hills from G.Ambang, Simut, Banga circling to the south and east way of D. Moat as the highest topography of the caldera wall.

3. Methods

The measurement data should be initial processed, ie some gravity correction (latitude correction, local elevation correction, topographic correction, tidal correction, and heterogenity correction which is often called as bouger correction). After that, we will get pre-processing result formed as .GRD and ready to be next processed. Overall, the above steps are illustrated in the flow-chart diagram (Figure 4). The final target in the research is extracting the horizontal and vertical map of geological structure distribution which is interpreted as geothermal fluid path (upflowing to manifestation)
4. Result and Discussion
This technology produces structural distribution imaging with their vertical depths. The determination of Euler Deconvolution solution has been done using structural zero index, with window 5 and 5% depth uncertainty value. The structural index is zero because the structural index represents the fracture structure. The width of the window used in this study is 5, because this window is considered representative and regional imaging structure in the resource area, so it can visualize the permeable zone combining with Geological map. The error depth value is 10% and indicating the depth solution used has an uncertainty value below 10%.

The distribution of permeable zones produced has varying vertical depths, especially in permeable zones in vertical flowing area (Gunung Muayat), ranging in depths of 370-700 meters. The result is so make sense where is the upflow area near to the heat source position and potentially to be drilled and releasing more hot area than the outflow area. Therefore, the nature condition of the rocks will be more soft and more sensitive to make cracking (in the form of fracture and easy to form mineral alteration [3]. While the permeable zone (geological structure) on the outflow area has a depth range of 150-570 meters. The permeable zone distribution of the Euler Deconvolution analysis inline with structural distribution based on geological mapping (represented on geological maps) and moreover contributing to increase permeable zones that is can’t be detected. Finally, we should to be constructed in the structure map overlying between Gravity Euler Deconvolution and Geology mapping in Figure 6.
Figure 6 Euler Deconvolution distribution overlying on topography map

Figure 7 Euler Deconvolution distribution overlying on geology mapping
5. Conclusions

Based on the results obtained from quantitative analysis of gravity and alignment mapping from the geological map of the research area, it can be concluded

- Geological structure generated by Euler Deconvolution method inline with the result of structural geological mapping, even has a more sensitive resolution. This is represented in some areas that permeable zone permeable also can be produced by Euler Deconvolution method.
- The geological structure generated by both methods is highly correlated and controls the existence of surface manifestations, both upflow and outflow.
- The geological structure as a fluid path to upflow manifestation (near the upflow manifestation) has a depth of 370-700 meters from surface, while as a fluid path to outflow manifestation (located along the outflow manifestation) has a depth ranging from 150-570 meters from surface.
- The experimental results show that the structure zone distribution of euler deconvolution is localized at a depth of 374 to 579 meters below the surface with the highest percentage 59%.

References

[1] Daud Yunus 2010 Diktat Kuliah Geothermal, Potensi, dan Eksplorasi Panasbumi Indonesia untuk Mengurangi Risiko Bisnis Panasbumi Laboratorium Geofisika FMIPA Universitas Indonesia Depok
[2] Dirjen Energi Baru Terbarukan dan Konservasi Energi-Kementrian ESDM 2016 Laporan Kinerja Jakarta
[3] Hendrasto Fajar 2016 Diktat Kuliah Mineral Alterasi Hidrotermal Departemen Fisika FMIPA Universitas Indonesia Depok
[4] Khyzhynak Mikola 2014 Thesis Geoelectric Strike and its Application in Magnetotelluric. University of Iceland
[5] PSD PGE 2011 Unpublished report about annual meeting Area Prospek Panas Bumi AA Sulawesi Utara Pertamina Geothermal Energy Jakarta
[6] Zhang C, Mushayandebyu MF, Reid AB, Fairhead JD, Odegard ME 2000 Euler Deconvolution of Gravity Tensor Gradient Data Geophysics 65 (2) 512-520