INTERPRETATION OF GRAVITY AND MAGNETIC DATA TO DELINEATE LOCAL FAULT STRUCTURES IN BUR NI GEUREUDONG GEOTHERMAL FIELD, ACEH PROVINCE, INDONESIA

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ABSTRACT

Fault structures play an important role in a geothermal system. Therefore fault mapping needs to be done in a geothermal field prior to further development. For this purpose, we have used gravity and magnetic methods to map subsurface fault structures in Bur Ni Geureudong geothermal field at District of Bener Meriah, Aceh Province, Indonesia. Gravity data were measured at 24 stations along 27 km, crossing the area in the NE-SW direction. To obtain complete Bouguer anomalies of the gravity data, measured data has been done drift, latitude, free air, Bouguer, and terrain corrections. The total magnetic field anomalies were obtained by applying diurnal and International Geomagnetic Reference Field (IGRF) corrections. The total magnetic field and the complete Bouguer anomalies were used for 2D forward modeling by applying Mag2DC and Grav2DC codes, respectively. These codes are based on 2D model of Talwani polygon. Both models show that the research area subsurface consist of three layers, mainly volcanic breccia superimposed by tuff and pyroclastic layers at the top and limestone estimated to be at the bottom layer. With regard to geothermal manifestations, the expected models also show four parallel normal faults directed in northwest – southeast, located in Wihni Durin, Tapak Muge, Wonosobo, and Bale Atu. The existence of fault line in Wonosobo is in agreement with location of Uning Bertih geothermal manifestation.

Keywords: geothermal, fault, Bur Ni Geureudong, geophysics, magnetic, gravity

1. INTRODUCTION

Geothermal energy is one of reliable, sustainable, and environmentally friendly alternative energy sources that may replace fossil energy in the future. However distribution of the geothermal resources in the world are limited, they are mostly found along active plate tectonic boundaries and volcanoes areas (Brehme, et al., 2014). Geological structures in such areas are complex, tectonic activities may create fault zones. The fault zones play an important role in hydrothermal system. The fault structures controlled heat source, fluid circulation, and permeability in volcanic hydrothermal system (Saibi, et al. 2012; Curewitz and Karson, 1997). Therefore understanding of the fault structures and hydrothermal flow is important to be fulfilled prior to development and exploitation of the geothermal sources.

Bur Ni Geureudong geothermal field has been not explored yet for further development. The area is situated in Bener Meriah District, Aceh Province, Indonesia. Bur Ni Geureudong is one of seven prospecting geothermal areas in Aceh Province, the most northwest of Sumatra Island. Most of geothermal field in Sumatra are formed by active Sumatran volcanic arc. The alignment of this volcanic arc is coincidence with the Great Sumatran Fault (GSF) system. This fault system is a major right lateral trench-parallel fault systems that accommodates a significant fraction of the strike-slip component of the oblique convergence between the Australian/Indian and Eurasian plates (Sieh and Natawidjaja, 2000). Because of this activity, there are found at least 30 geothermal prospecting areas along Sumatra Island (Hochstein, et al., 1993).

An area with presence of volcano is considered active geologically. Some structures like joints, fractures, and faults can be created around the area as results of instability accumulated in short or long period. The fractures and faults system allow magma from in the deeper part of the earth arise at shallow depth as well as to the surface (Lagmay, et al., 2000). Hydrothermal systems are also created in such fractures and fault zones (Saibi, et al., 2112).

Gravity and magnetic methods are believed as fast, reliable, and economically cost effective of geophysical techniques that can be used for fault structure investigation beneath geothermal areas. In gravity method, we measure spatial variation of gravity anomalies due to distribution of densities beneath the subsurface. Where sharp changes in gravity are present, the gravity anomaly data can be used to model possible faulting in the subsurface. Gravity measurement, in some cases, also work well to identify the main flow paths of hydrothermal along its faults (Sircar, et al., 2015; Gupta, et al., 2007; Aydogan, 2011). While magnetic method for geothermal exploration can be used to detect variation of magnetic susceptibility of alteration rocks in hydrothermal system. Hydrothermal alteration rocks are mostly dominated by relatively high susceptibility magnetic compared to the unaltered rocks. Interaction between rocks and hydrothermal fluids altered the origin rocks to new rock types (Pandarinath, et al., 2014).

2. GEOLOGICAL SETTING OF THE STUDY AREA

Bur Ni Geureudong is one of active Sumatran volcanic arc in District of Bener Meriah, central part of Aceh Province, Indonesia. Although the configuration of the Sumatran volcanic arc and the Great Sumatran Fault is coincidence (Sieh and Natawidjaja, 2000), position of Bur Ni Geureudong is separated about 50 km northeast to the Great Sumatran Fault. Bur Ni Geureudong is a stratovolcanic complex with diameter about 18 km. The volcano has two young parasite volcanic cone at the south, namely Bur Ni Telong and Pepanji. The summit of Bur Ni Geureudong is 2.624 m above sea level (Barber, et al., 2015). Geothermal potential of this volcano is proved by presence of some geothermal manifestations at the surface.

Figure 1 show geological map of Bur Ni Geureudong area. The area is dominated by deposit of Enang-enang volcanic rocks (*Qvee*) consists of mid-Pleistocene volcanic sedimentary (*Poltmict*), Pepanji volcanic deposit (*Qvp*) formed by deposit of mid Pleistocene sediment (*polymict*), Tuan-tuan volcanic deposit (*Qtvtu*) formed by early Pleistocene (*polymict*) sediment, and Telong vocanic rocks (*Qvtg*) formed by lava volcanic sedimentary from mid Holocene (Mining and Energy Agency of Central of Aceh District, 2016).

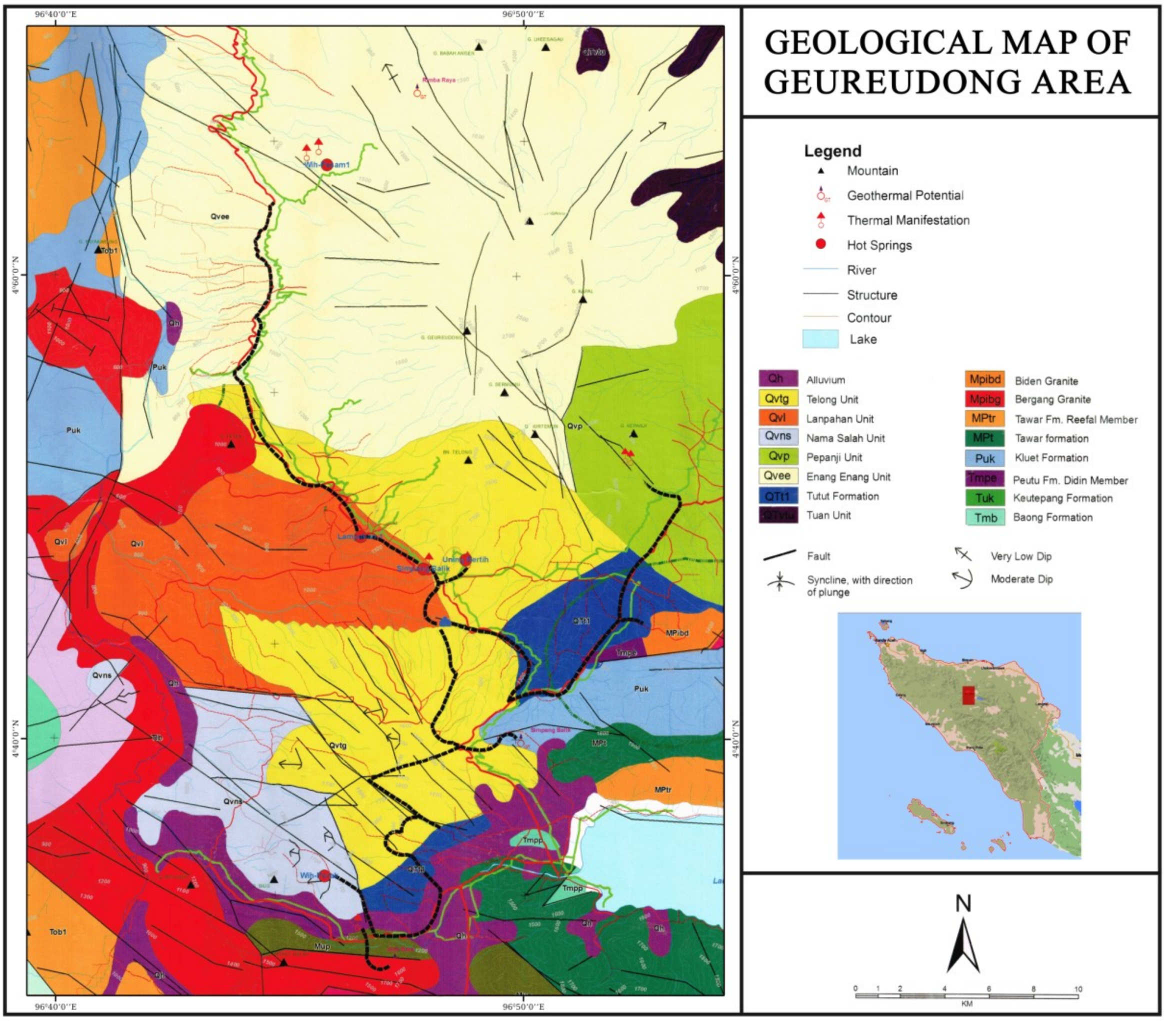

Fig. 1 Geological map of Bur Ni Geureudong area (Mining and Energy Agency of Central of Aceh District, 2016).

3. DATA ACQUISITION AND MODELING

We have measured gravity field and total magnetic field data along a profile at the southern part of Bur Ni Telong (Fig. 2). The profile orientation is in SW-NE direction with 27 km distance crossing the Pepanji summit volcano complex. There are 24 stations along the profile and the distant between stations are irregular because of logistic problem. Feature of the area is topographic and the land use is mixed between coffee plantation and rain forest.

The gravity field data were measured using Scintrex CG-5 autograv gravitymeter with resolution 10^{-3} mGal reading resolution. While the total magnetic field data were collected using Proton Precision Magnetometer (PPM) GEM system. Several standard corrections have been applied to the gravity field and total magnetic field data set so that the anomaly data reflected from the geological targets are acquired. Complete Bouguer anomaly of the gravity field data were calculated from a series of drift, tide, elevation, latitude, free air anomaly, Bouguer, and terrain corrections. For the magnetic measurement, data corrections are simple. Total magnetic field anomaly data calculated from the data field after diurnal and International Geomagnetic Reference Field (IGRF) correction.

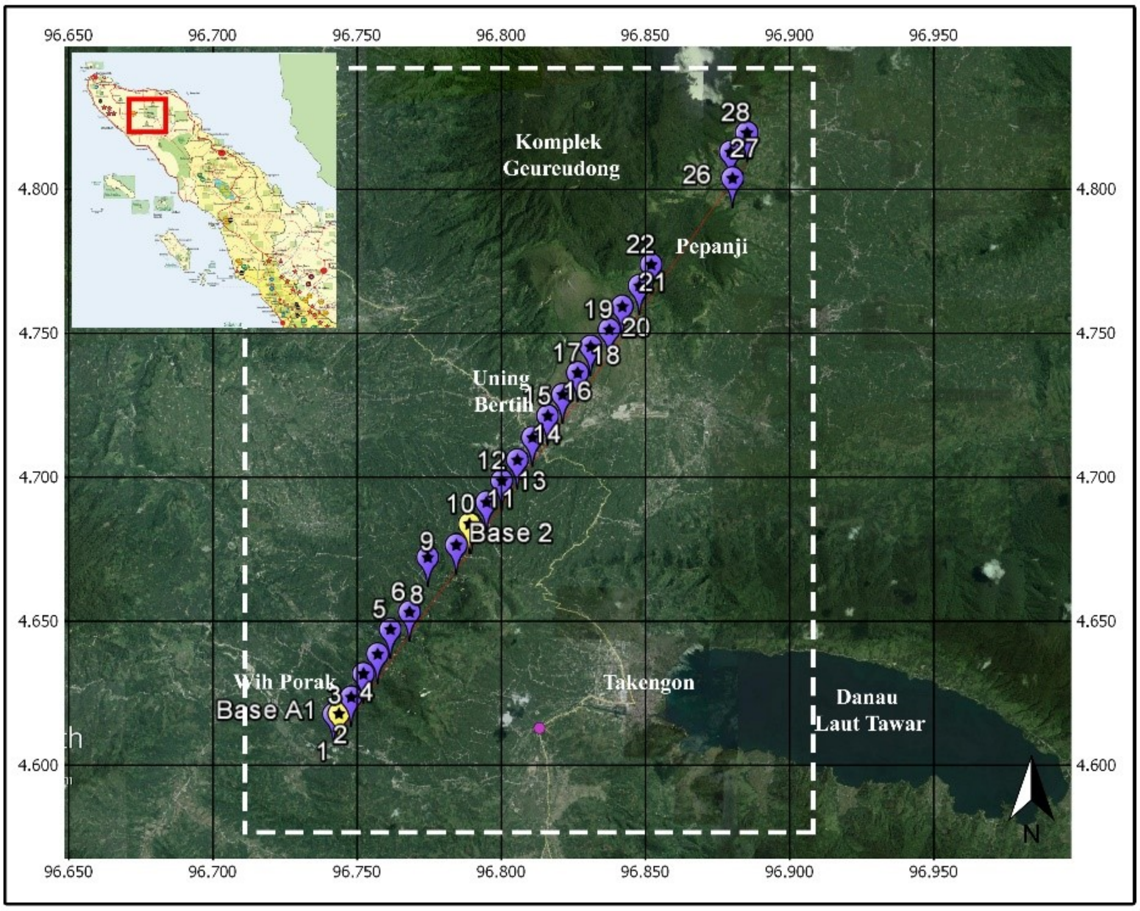

Fig. 2 Profile of gravity and magnetic stations plot on Google image (Google™, 2016). The blue markers show location of the stations and the yellow markers are base stations.

The complete Bouguer anomaly data were used for 2D forward modeling code of Grav2DC (Cooper, 1998). The total magnetic anomaly data were modeled using forward 2D modeling of Mag2DC (Cooper, 1997). The 2D forward modeling of Grav2DC and Mag2DC codes are based on 2D models of Talwani polygon. In forward modeling, an initial model for the source body is constructed based on geologic and geophysical intuition. The model's anomaly is calculated and compared with the observed anomaly, and model parameters are adjusted in order to improve the fit between the two anomalies (Blakely, 2005). Fig. 3 show 2D modeling of Complete Bouguer anomalies using Grav2DC (left) and total magnetic field anomaly using Mag2DC (right). Models are represented by density contrast for gravity data and susceptibility contrast for magnetic data (indicated by colors in the lower part of the figures). The upper part show data fit between observed data (solid line) and calculated data (dashed line).

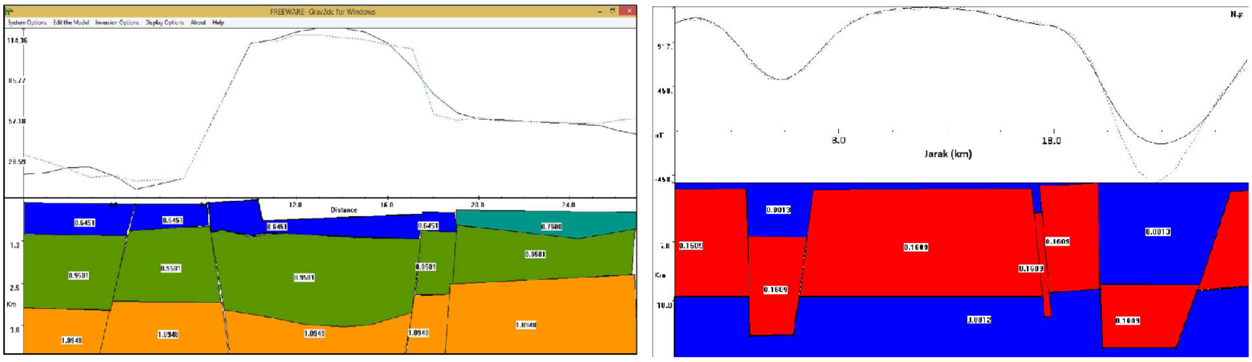

Fig. 3. 2D modeling of Complete Bouguer anomalies using Grav2DC (left) and total magnetic field anomaly using Mag2DC (right). Models are represented by density contrast and susceptibility contrast (indicated by colors in the lower part of the figures). The upper part show data fit between observed data (solid line) and calculated data (dashed line).

4. RESULTS AND DISCUSSSION

The 2D models of subsurface structures obtained from complete Bouguer anomaly and total magnetic field anomaly are shown in Fig. 4 and Fig. 5, respectively. Based on the 2D forward modeling, the gravity anomaly inferred that the subsurface of study area are constructed by 3 layers. They are mostly dominated by volcanic rocks composed by some geological unit (Fig. 4). The uppermost thin layer is named as Silih Nara unit (*Qvns*) composed by tuffs (ρ=2.34 gr/cm^3), Telong unit (*Qvtg*) dominated by dacitic lava, breccia, and tuff (ρ=2.34 gr/cm^3), and Pepanji unit (*Qvp*) made by pyroclastic breccia (ρ=2.45 gr/cm^3). The tuff layer is expected as cap rock since the layer is mostly impermeable. The second layer is composed by Geureudong unit (*Qvee*) dominated by volcanic breccia (ρ=2.65 gr/cm^3). Hydrothermal reservoir is expected within this layer. The lowest layer is Kluet Formation (*Puk*) composed by limestone (ρ=2.7 gr/cm^3).

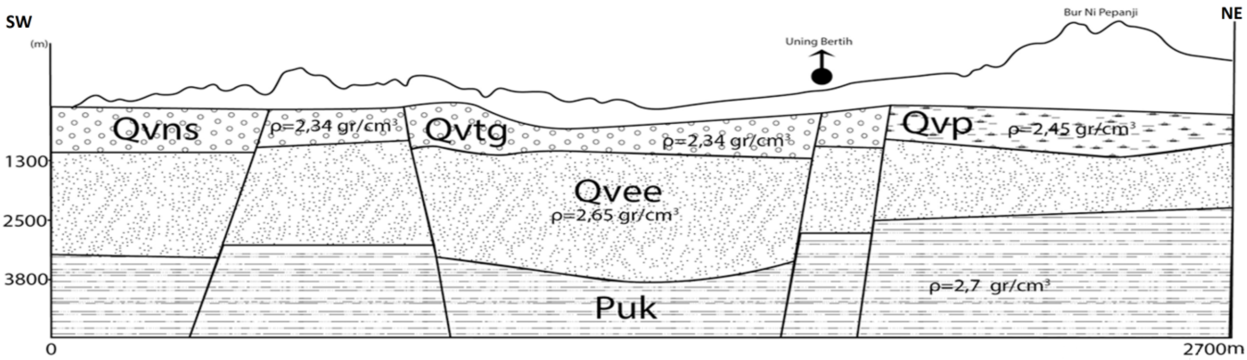

Fig. 4 The 2D cross section model derived from 2D forward modeling of complete Bouguer gravity anomaly.

Subsurface model of total magnetic field anomalies is calculated based on physical parameter of rocks susceptibility. The 2D model derived from the total magnetic field anomalies is shown in Fig. 5. As we found in the gravity model, the magnetic model are composed also by 3 layers sedimentary rocks. The most upper part sediment is dominated by volcanic rocks (k = 0.0004). This layer is recognized as

Silih Nara unit (*Qvns*) made up by dacitic lava and tuffs, Telong unit (*Qvtg*) consist of dacitic lava, breccia, and tuffs, and Pepanji unit (*Qvp*) with tuffs and pyroclastic breccia. The second layer is namely Geureudong unit (*Qvee*) dominated by andesitic lava, pyroclastic breccia, and tuffs (k = 0.1609). The lowest layer is Kluet formation (*Puk*) that mostly dominated by limestone (k = 0.0003).

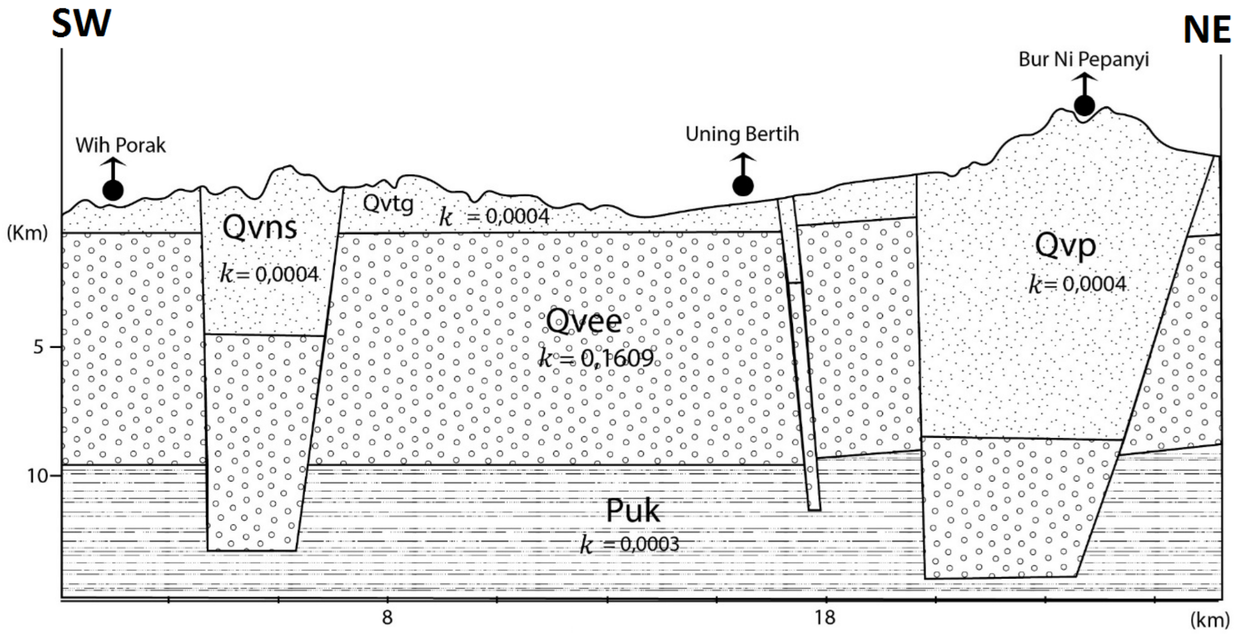

Fig. 5 The 2D cross section model derived from 2D forward modeling of total magnetic field anomalies.

Regarding to the fracture and fault system, the 2D model derived from the gravity anomalies and the total magnetic field anomalies also show some normal faults crossing the profile. In gravity model there are 4 faults, but in magnetic model the best data fit reached by constructing 6 faults models along the profile. However 4 faults found in gravity model is also reveal by the magnetic model. These faults are located at Desa Wihni, Tapak Muge, Wonosobo, and Bale Atu from the SW to NE along the profile. Geothermal manifestation at Uning Bertih is located close to the fault at Wonosobo. These faults play role as medium transport of fluids in the hydrothermal system.

5. CONCLUSIONS

- Gravity and magnetic methods are considered as fast, reliable, and economically cost effective of geophysical techniques that can be used for fault structure investigation beneath geothermal areas.
- Based on 2D models derived from the complete Bouguer anomalies of gravity data and total magnetic field anomalies, geological subsurface of Bur Ni Geureudong geothermal field is formed by 3 layers of sedimentary rocks and some local faults in NW-SE direction.
- The 3 layers composed in the 2D models can interpreted as volcanic breccia superimposed by tuff and pyroclastic layers at the top and limestone estimated to be at the bottom layer.
- With regard to geothermal manifestations, the expected models also show four parallel normal faults directed in northwest – southeast, located in Wihni Durin, Tapak Muge, Wonosobo, and Bale Atu. The

existence of fault line in Wonosobo is in agreement with location of Uning Bertih geothermal manifestation.

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