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Geophysics Field Camp (GFC): A Student Project Aimed to Investigate the Low to Moderate Temperature Geothermal System in Mt Pancar Area, Bogor (Indonesia)

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ABSTRACT

Geophysics Field Camp (GFC) is a curriculum related project conducted by undergraduate students of the Department of Physics (Geothermal Laboratory), the University of Indonesia. The project is designed to educate the students in understanding a geophysical project from survey design, data acquisition, data processing, through modeling and interpretation. In addition, geological mapping and geochemical survey are also added to support the geophysical data. Mt Pancar geothermal prospect is located in the Bogor district, West Java Province, Indonesia. The geological condition of the area consists of Tertiary volcanic formation of the Mt. Pancar and Quartenary volcanic formation of Mt. Panisan covering Tertiary sedimentary formation. The surface manifestations found in this geothermal area are hot springs, warm grounds and altered rocks. The hot springs are found in Kawah Merah (T = 70^{o}C) and Kawah Putih (T = 51^{o}C) with neutral pH and minor silica sinter. There is no indication of thermal activity on the summit of Mt Pancar. The subsurface temperature, as indicated by Na/K geothermometry, is in the range of 180-190^{o}C. Based on the preliminary information it can be concluded that the Mt Pancar geothermal area can be classified as a low to moderate geothermal resource. To develop initial conceptual model of the geothermal system, geophysical investigations including Audio-frequency Magnetotelluric (AMT) and gravity surveys were then carried out. Ten soundings of AMT data were accomplished along two profiles both crossing Mt Pancar summit and the other ends crossing Kawah Merah (Line AB) and Kawah Putih (Line CD) hot springs area, respectively, whereas gravity survey was conducted on 155 stations in a grid survey design. Three-dimensional inversion of AMT data was then carried out along the profile lines using MT3DInv-X software. The results show a conductive layer (< 15 ohm-m) from near surface down to about 2000 meter depth. The conductive layer is interpreted as the clay cap of the geothermal system distributed between Mt. Pancar and Kawah Merah (Line AB) and Mt. Pancar and Kawah Putih (Line CD). The slightly resistive layer (20 – 100 ohm-m) was also found underlying the clay cap which is interpreted as the reservoir zone. A more resistive basement (> 100 ohm-m) was encountered forming structure-like graben. The graben structure possibly controls the hydrothermal system in Mt Pancar area. In addition, 2-dimensional gravity modeling using Grav2D-X software supports the resistivity inversion results. Integrated interpretation was then accomplished by incorporating AMT and gravity data supported by geological and geochemical data. Based on this study, a conceptual model of the MT Pancar Geothermal Area was developed to explain the geothermal occurrence in this area.

1. INTRODUCTION

Indonesia is a country blessed with huge geothermal resources. Geological Agency of Indonesia estimates the geothermal resources in Indonesia of about 28,617 MWe. The recent installed capacity is a total of 1,341 MWe from seven power plants mostly owned by Pertamina Geothermal Energy. Additional power plants are now being prepared in several geothermal fields in Java and Sumatera. Preliminary survey and exploration activities are also being conducted in many geothermal prospect areas in Indonesia. Accordingly, Indonesia needs human resources with various aspects of geothermal expertise. The university has a key role in educating young geoscientists and engineers with expertise in geothermal aspect. For this purposes, the University of Indonesia has been conducting geothermal education for undergraduate and graduate students from concept through applications. This paper describes the geothermal education program in the University of Indonesia for undergraduate students, especially Geophysics Field Camp (GFC), and its results.

2. GEOPHYSICS FIELD CAMP

Geophysics Field Camp (GFC) is a curriculum based project conducted by undergraduate students of the Department of Physics (Geothermal Laboratory), the University of Indonesia. The project is designed to educate the 4th year undergraduate students in geothermal exploration by conducting field survey. The GFC is aimed at building understanding of a geophysical project from survey design, data acquisition, data processing, through modeling and interpretation. In addition, geological mapping and geochemical survey are also conducted to support the geophysical data.

The GFC project is led by a team of lecturers and supported by 4-5 assistants (mentors). An undergraduate class with geophysical major consisting of 25-30 students participates in the GFC. To achieve the objective and to manage time and resources, the class is then divided up to 4 to 5 groups. Each group consists of 5 to 6 students assisted by one mentor. Each group should manage geological, geochemical and geophysical surveys. Geological survey includes geological field observation and mapping, while geochemical activities consist of sampling and analyzing fluids from hot springs. Since the allocated time is limited (only 4 days) the lecturing team manages the program tightly.

The GFC survey is conducted in Mt Pancar geothermal prospect area, Bogor District, West Java. All the activities are managed in a basecamp owned by a local resident. The basecamp consists of two cottages with natural style, one for male students and one for female students. The field survey activities start from 7 a.m and finished at 5 p.m. Evening time is allocated for evaluation of field survey activities and preparation for the next day program. Moreover, data processing is also conducted in the evening time.

3. FIELD REVIEW

Mt Pancar geothermal prospect is located in the Bogor District, West Java Province, Indonesia about 40 km to the south of Jakarta (Figure 1). The location can be reached from UI Depok campus about in 90 minutes. The geological conditions of the area consist of Tertiary volcanic formation of the Mt. Pancar and Quaternary volcanic formation of Mt. Panisan covering Tertiary sedimentary formation as basement (Figure 2). The geological structure is dominated by northwest – southeast structure orientation (Figure 2). The surface manifestations found in this geothermal area are hot springs, warm grounds and altered rocks controlled by a fault structure. The hot springs are found in Kawah Merah (T = 70^{o}C) and Kawah Putih (T = 51^{o}C) with neutral pH and minor silica sinter. There is no indication of thermal activity on the summit of Mt Pancar. The subsurface temperature, as indicated by Na/K geothermometry, is in the range of 180-190 ^{o}C. Based on the preliminary information it can be concluded that the Mt Pancar geothermal area can be classified as a low to moderate geothermal resource. However, there are still questions about the geothermal system in Mt Pancar: (1) What is the geothermal conceptual model? (2) Is it a stand-alone system with mother source from Mt Pancar or is it an outflow system of Mt Gede-Pangrango (25 km to the southeast of Mt Pancar)? The GFC attempts to answer those questions from Mt Pancar's point of view.

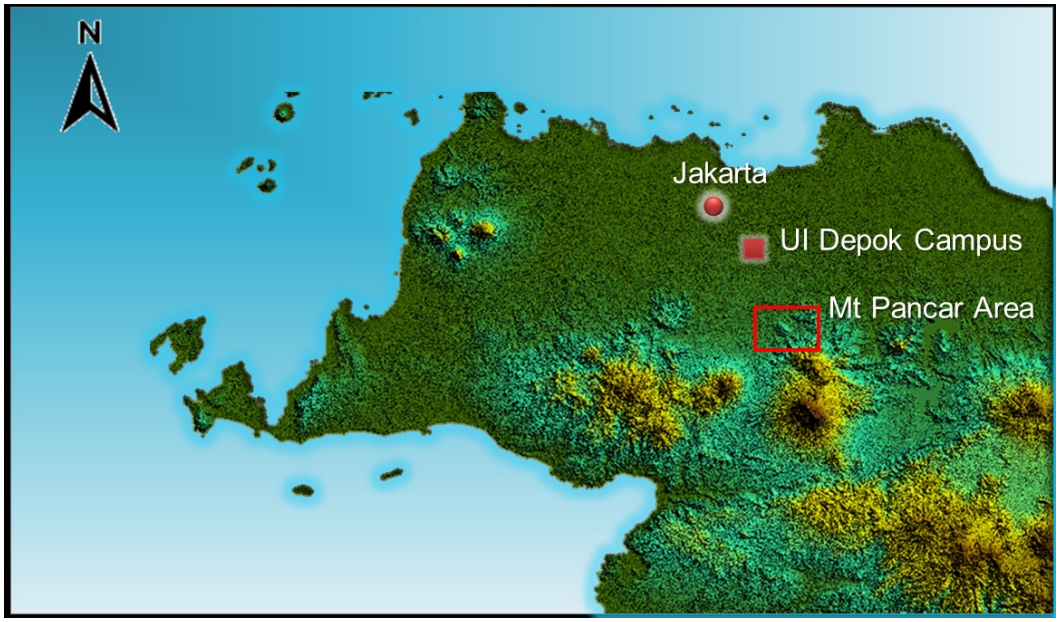

Figure 1: Location Map of Mt Pancar Geothermal Prospect Area.

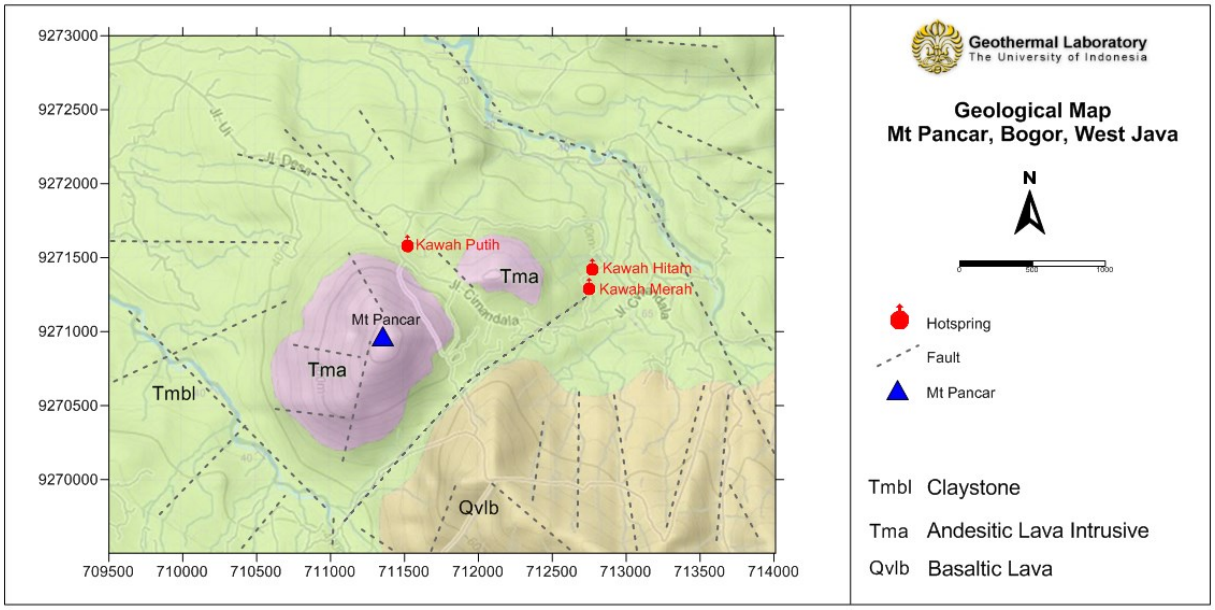

Figure 2: Geological Map of Mt Pancar Geothermal Prospect Area.

4. METHOD REVIEW

GFC is conducted to educate undergraduate students in applying geophysical methods in geothermal exploration. Furthermore, the geophysical survey is intended to develop an initial conceptual model of the MT Pancar geothermal system. To achieve the objectives, two geophysical methods are selected including gravity and Audio-frequency Magnetotelluric (AMT) surveys. Gravity survey is aimed at delineating the geological structure, basement or possible plutonic body, whereas the AMT survey is intended for delineating possible altered rock associated with hydrothermal activities, possible geological structure and basement rock.

In addition, gravity survey was planned to be conducted on 155 stations in a grid survey design (Figure 3). However, since the production of measurement is limited, the survey design was implemented gradually (part by part) starting from the GFC 2008 to 2013. The Gravity survey was conducted using Scintrex Gravimeter CG-5. The number of gravity measurement stations for each GFC survey was about 25. The total number of gravity stations already measured until 2013 was 155. The standard calculation, reduction and correction of the gravity data using GravPro-X software (developed by NewQuest Geotechnology) was then applied to obtain Complete Bouguer Anomaly (CBA). The residual gravity anomaly was also calculated by applying trend surface analysis. Two-dimensional modeling of the residual gravity anomaly was then carried out to reconstruct the subsurface density model.

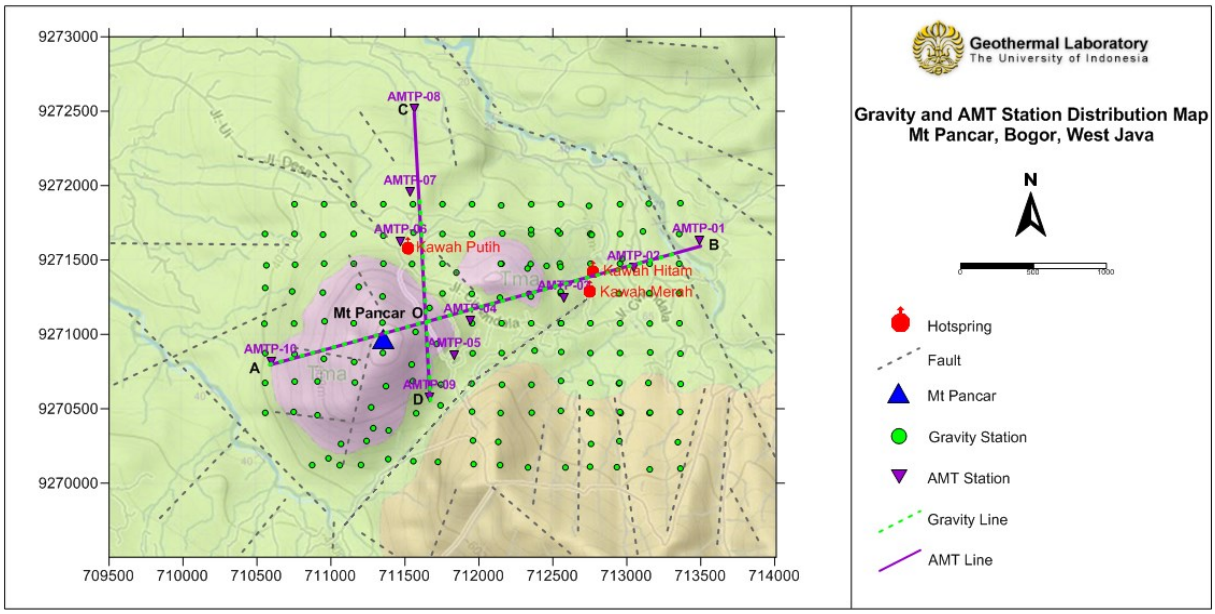

Figure 3: Distribution of Gravity and AMT Measurement Stations in Mt Pancar Geothermal Prospect Area.

Ten soundings of AMT data were accomplished along two profiles both crossing Mt Pancar summit and the other ends crossing Kawah Merah (Line AB) and Kawah Putih (Line CD) hot springs area, respectively (Figure 3). The AMT survey was conducted using Phoenix equipment system. The duration of measurement was about 2 hours per station. The frequency range is from 0.1 Hz to 10 kHz. Data processing was carried out using SSMT2000 software. The AMT data quality was good to excellent. 2-D and 3-D inversions of the AMT data were then carried out along the profile lines using WinGLink software and MT3DInv-X, respectively.

Results of 2-D gravity modeling and 3-D inversion of AMT data were then integrated to develop a conceptual model of Mt Pancar geothermal prospect area.

5. RESULTS AND DISCUSSIONS

Complete Bouguer Anomaly (CBA) map is shown in Figure 4, while Residual Bouguer Anomaly (RBA) map is presented in Figure 5. As shown in both maps, the distribution of contours of CBA and RBA has similarities. The distribution of CBA is dominated by a low anomaly in the central part of Mt Pancar area extending to the north and to the east surrounded by a high gravity anomaly. The low gravity anomaly is interpreted as the graben-like structure. In addition, the hot springs are located at the margin of the graben-like structure, controlled by faults. To reconstruct the subsurface density model of the Mt Pancar area, two-dimensional gravity modeling was carried out along the Line AB and Line CD using Grav2D-X software developed by NewQuest Geotechnology. As shown in Figure 6, the subsurface density model along the east-west profile is dominated by graben-like structure. Moreover, the subsurface density model over the north-south profile shows the graben-like structure (Figure 7).

The AMT data was inverted using 3-D inversion algorithm to get the subsurface true resistivity distribution. The results were then shown as the resistivity section of the east-west and north-south profiles similar with the gravity profiles (Figure 8 and Figure 9). As shown in the two profiles, the subsurface resistivity distribution in the Mt Pancar area is dominated by low resistivity layer (< 15 ohm-m) distributed from near surface down to about 2000 meter depth. The low resistivity layer is interpreted as the clay cap of the Mt Pancar geothermal system distributed between Mt Pancar and Kawah Merah (Line AB; Figure 8) and between Mt Pancar and Kawah Putih (Line CD; Figure 9). The up-dome shape of the base of the conductive layer indicates an upflow zone. The slightly resistive layer (20 – 100 ohm-m) was also found underlying the clay cap which is interpreted as a reservoir zone. The more resistive basement (> 100 ohm-m) was encountered forming graben-like structure as indicated by the gravity data. The graben-like structure possibly controls the hydrothermal system in Mt Pancar area as indicated by the occurrence of hot springs.

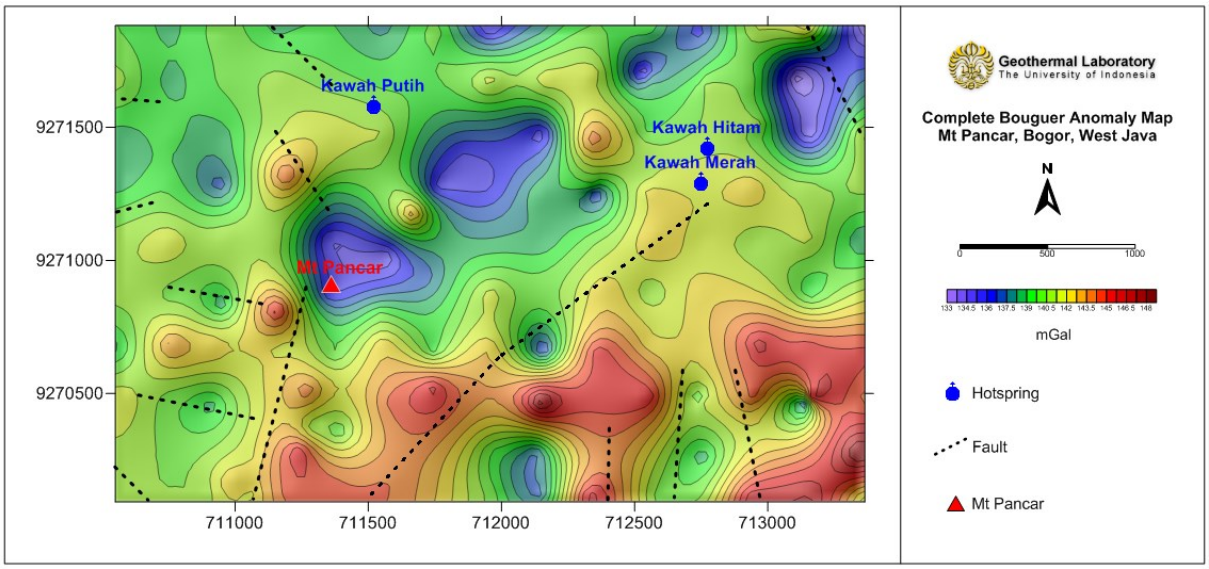

Figure 4: Complete Bouguer Anomaly (CBA) in Mt Pancar Geothermal Prospect Area.

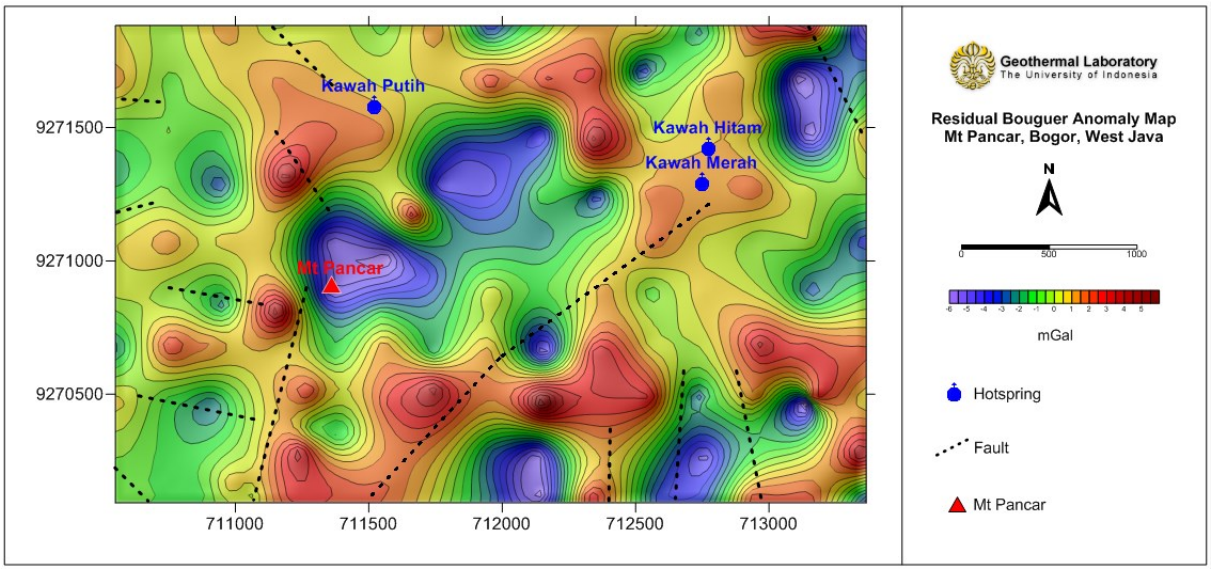

Figure 5: Residual Bouguer Anomaly (RBA) in Mt Pancar Geothermal Prospect Area.

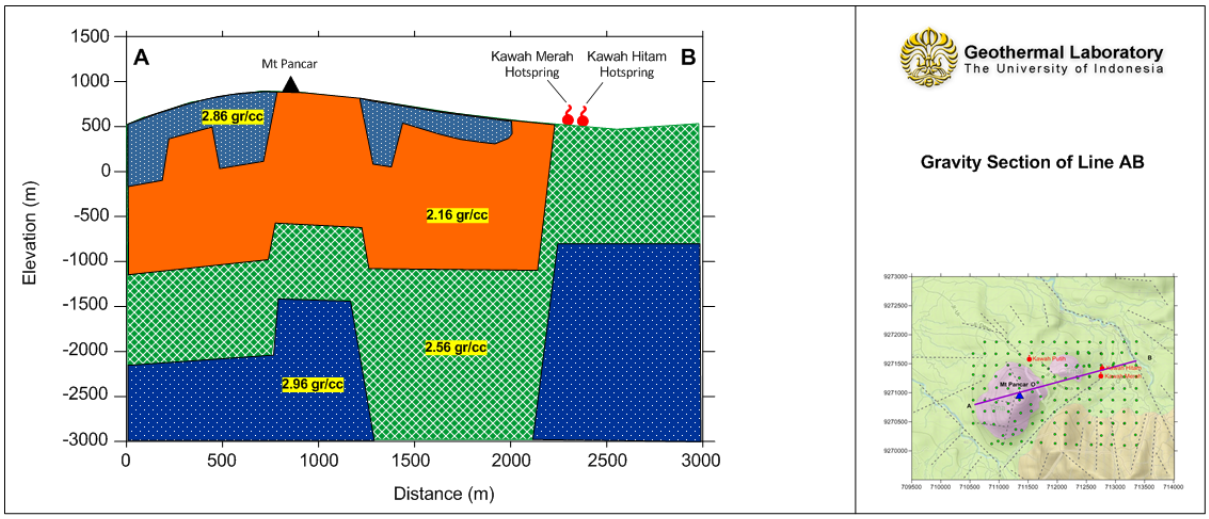

Figure 6: 2-D Gravity Modeling Along Line AB.

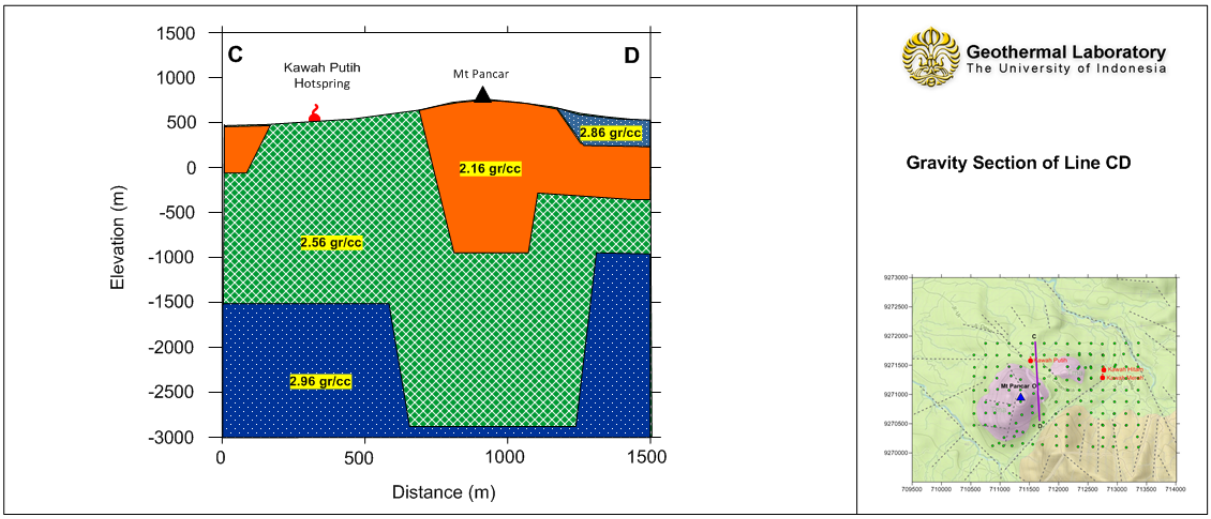

Figure 7: 2-D Gravity Modeling Along Line CD.

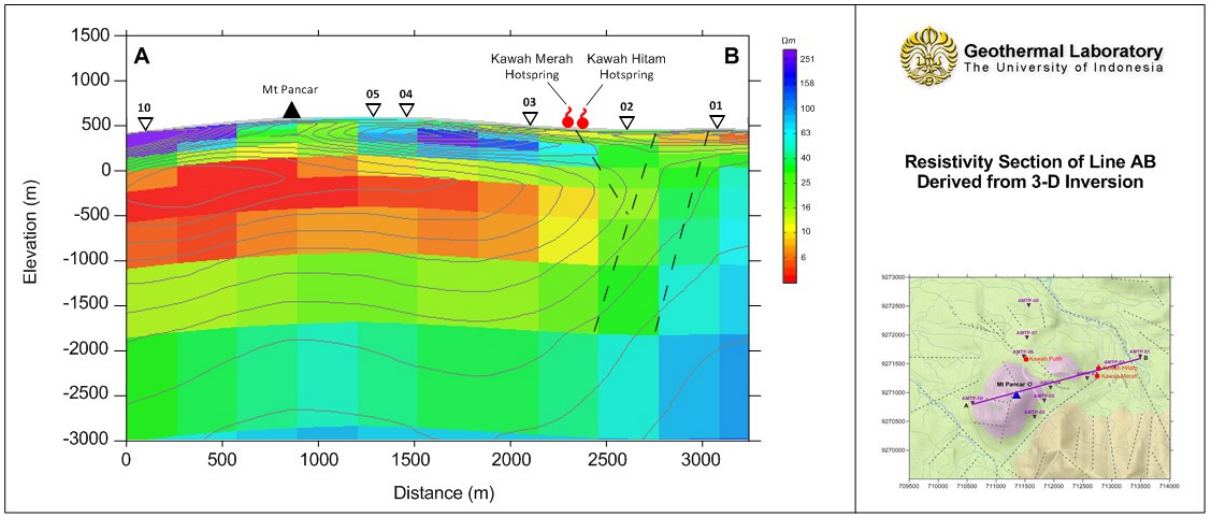

Figure 8: Resistivity Section Derived from 3-D Inversion of AMT Data (Line AB).

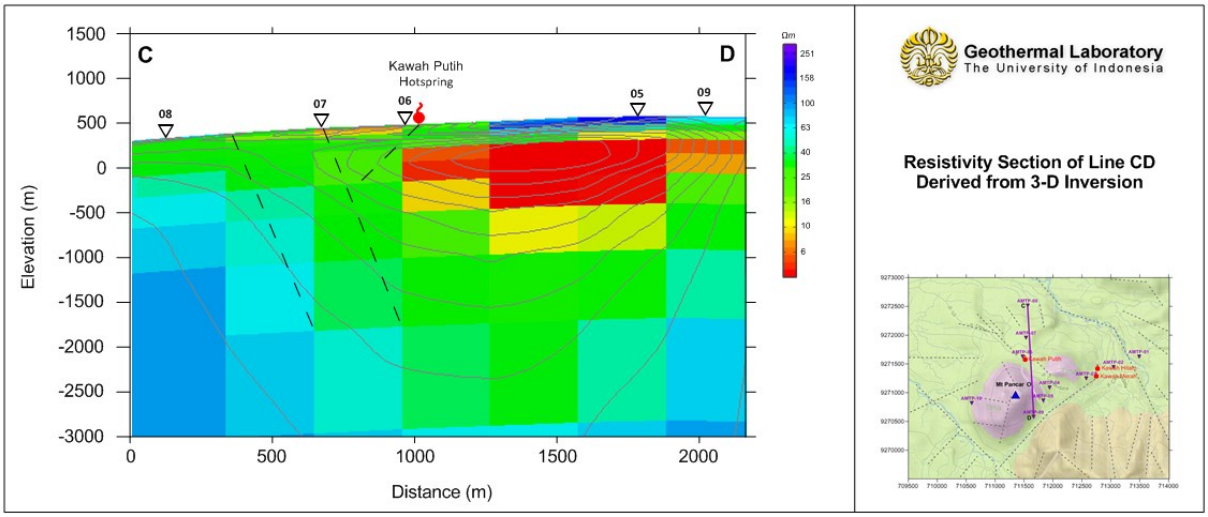

Figure 9: Resistivity Section Derived from 3-D Inversion of AMT Data (Line CD).

Integrated interpretation was then accomplished by incorporating AMT and gravity data supported by geological and geochemical data to develop the conceptual model of the MT Pancar Geothermal Area. Figure 10 shows the conceptual model of Mt Pancar geothermal area. The possible up-flow zone is inferred in the vicinity of Mt Pancar summit as indicated by the up-dome shape of

the conductive layer. While the outflow zone is indicated towards the north where the Kawah Putih hot spring occurs, as well as towards the east, where the two hot springs, Kawah Merah and Kawah Hitam, are found. There is still a crucial question concerning the inference of the up-flow zone, since no surface manifestation is found in the vicinity of Mt Pancar summit. Temperature gradient drilling should therefore be recommended in this location to confirm the subsurface temperature.

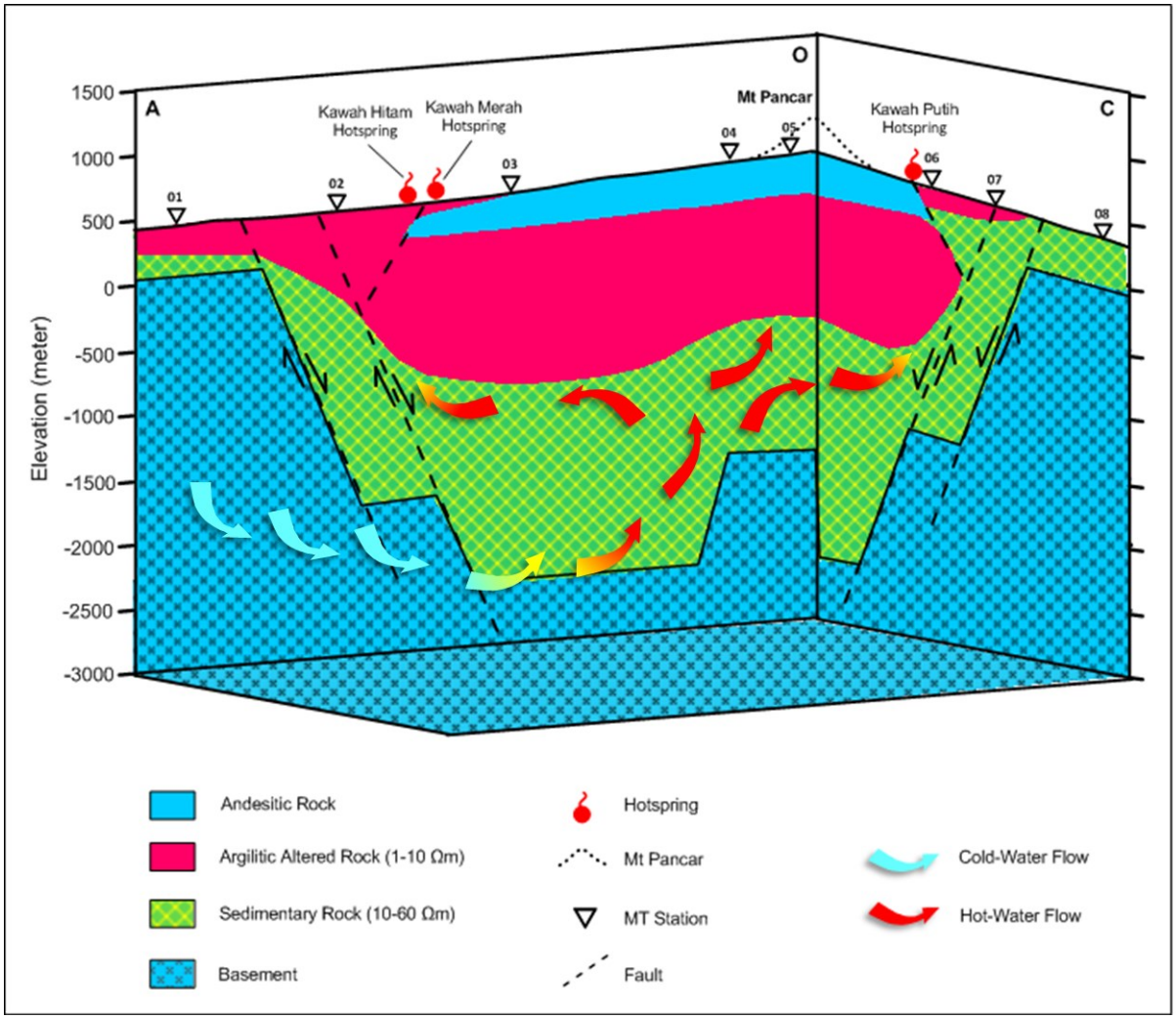

Figure 10: Conceptual Model of Mt Pancar Geothermal Prospect Area.

6. CONCLUSIONS

Geophysics Field Camp (GFC) is a program focusing on educating undergraduate students in applying geophysical survey for geothermal prospecting. It is a serial project conducted annually for 4th year students. The GFC is focused on investigating Mt Pancar geothermal prospect area located in Bogor District, West Java. Mt Pancar geothermal prospect is a low to moderate geothermal system. Geological, geochemical and geophysical (AMT and gravity) studies have revealed the possible hydrothermal system model in the survey area. 3-D inversion of AMT data and 2-D modeling of gravity data could reveal the possible subsurface physical properties (i.e. resistivity and density) associated with hydrothermal activities. An upflow zone is inferred below the northern vicinity of Mt Pancar summit as indicated by an up-dome shape conductive layer, while the outflow zones are presumed to the north and east of Mt Pancar as indicated by the occurrence of Kawah Merah and Kawah Putih hot springs, respectively. Concerning the inference of the upflow zone, since no surface manifestation is encountered in the vicinity of Mt Pancar summit, it can be recommended to drill a temperature gradient well to confirm the subsurface temperature.

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