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Specific Characteristics of the Gravity Analysis Within the Ulubelu Geothermal System Tanggamus, Lampung Indonesia

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ABSTRACT

Interpretation of a gravitiy survey has been carried out in the Ulubelu geothermal system. Detailed data within the geothermal system have been collected, then processed and interpreted. Density is determined by measuring the cores and cuttings and interpreted using the Parasnis and Nettleton methods. Geobodies were modeled using a three dimensional gravity inversion program.

The gravity model shows that four specific models occur in the Ulebelu geothermal system. The caldera or graben groups outlined in the study area, are at an average dept of about 3 km below the surface. The permeable area outlined in in the survey surrounds Mt. Duduk and spreads out to the northern part of the study area.

1. INTRODUCTION

A gravity investigation was conducted to study the geological structures, distribution and dimensions of subsurface lithology in the Ulubelu geothermal system. Several regional gravity surveys have been carried out in the RUW geothermal system. The gravity map of Kota Agung Quadrangle, scale 1: 250,000, was published by the Geological Survey of Indonesia in 1991 (Buyung et al., 1991). The regional gravity data over the whole of Southern Sumatra (Walker, 1993) indicates a shallowing of the pre-Tertiary basement southwards (Amin et al., 1994). The regional gravity background values are higher in the Lampung area than elsewhere in Southern Sumatra. Walker (1993) reported a much shorter wavelength of gravity signature in the southern part of Southern Sumatra indicating a shallow metamorphic basement there. Amin et al. (1994) recognized a local gravity low in the RUW geothermal system and suggested that it is associated with a volcanic center. They also inferred the presence of several faults from the dominant northwest-southeast, northeast-southwest and north-south trends around the gravity low. Part of the Bouguer anomaly map of Kota Agung Quadrangle (Buyung et al., 1991) covering the Ulubelu geothermal system (Suharno, 2005). The Bouguer corrections were computed using a terrain density of 2.67 x 10^3 kg m^{-3}. The effects of topographic undulations (the terrain correction) were not all included in the reduction of these Bouguer anomalies in the map.

2. METHOD AND PROCESSING

2.1 Data Acquisition and Processing

The gravity data used were collected by Pertamina (1991/92) from about 500 gravity stations established over the Ulubelu geothermal prospect. These stations were located along several lines at about 250 meters spacing.

The gravity measurements were conducted using a La Coste-Romberg Gravimeter type G 655, which has a sensitivity of about 0.2-0.4 µN kg^{-1}. Other characteristics of this gravimeter are given in most standard geophysical textbooks (e.g. Parasnis, 1997). During the RUW survey, the measurement drifts of the gravitymeter were linearly interpolated (with respect to time) from the differences of readings made at the same base station.

The Bouguer anomalies were reduced using a Bouguer density of 2.67 x 10^3 kg m^{-3}. The terrain corrections were adopted from the values given by Rahman et al. (1991/1992).

2.2 Density of the Rocks measurement

Information about the density of rocks is necessary to interpret gravity data. Rock densities were measured from some borehole samples in the study area. A total of 20 samples of fine grained cuttings from the wells Kd, Kukusan I (Kk1) and Kukusan II (Kk2), and 25 samples of coarse cuttings from wells Ulubelu II (UBL2) and Ulubelu III (UBL3) were measured.

2.3 Gravity Modeling

Quantitative interpretations of the gravity data over the Ulubelu geothermal system were made using three-dimensional gravity modeling because of the simple patterns of residual anomalies shown in Figures 2-5. The modeling was conducted using Grav3D Version2.0, A Program Library for Forward Modelling and Inversion of Gravity Data over 3D Structures; UBC-Geophysiscal Inversion Faculty Department of Earth on Facility; Department of Earth and Ocean Sciences; University of British Columbia, Vancouver, British Columbia; January, 2001.

3. RESULT AND DISCUSSION

3.1 Gravity Data Reduction

The reduction of the Bouguer anomaly is described and presented as a contour map on Figure 1. The Bouguer anomalies computed for this study are compatible with those of the previous investigations only in the eastern part of the area. In the western part, these two maps differ, mostly because of incomplete station coverage of the previous investigations. As mentioned in section by Suharno (2003), topographic effects were not removed during the reduction of Bouguer anomalies by Buyung et al. (1991). Overall, the Bouguer anomalies obtained for this study are of a much better quality than those obtained from the previous investigations. Hence, only the data shown in Figure 1 are used for the gravity interpretations made in this study.

3.2 Density of the Rocks

The results of the density measurements of cores and cuttings show that the range of the values is between 2.60 x 10^3 kg m^{-3} and 2.70 x 10^3 kg m^{-3}. Three of the wells, UBL2, Kk1 and Kk2, are located on Mt. Kukusan basaltic andesite lava (Suharno, 2003). The measured density values correlate with the rock types penetrated by these wells. Wells UBL2 and Kk1 are close to the boundary with Mt. Rendingan pyroclastics. The other two wells, UBL3 and Rd, are located within Mt. Rendingan pyroclastics. Well UBL3 is located in the middle section, but well Rd is close to its boundary with Mt. Rendingan andesite lava. The results show similar mean densities, about 2.67 x 10^3 kg m^{-3}, for wells Rd, UBL2 and UBL3. A lower mean density of about 2.63 x 10^3 kg m^{-3} is shown by samples from wells Kk1 and Kk2. These wells (Kk1 and Kk2) are located on exposures of Mt. Kukusan basaltic lavas but they penetrate less dense tuffs at depth (Suharno, 2003).

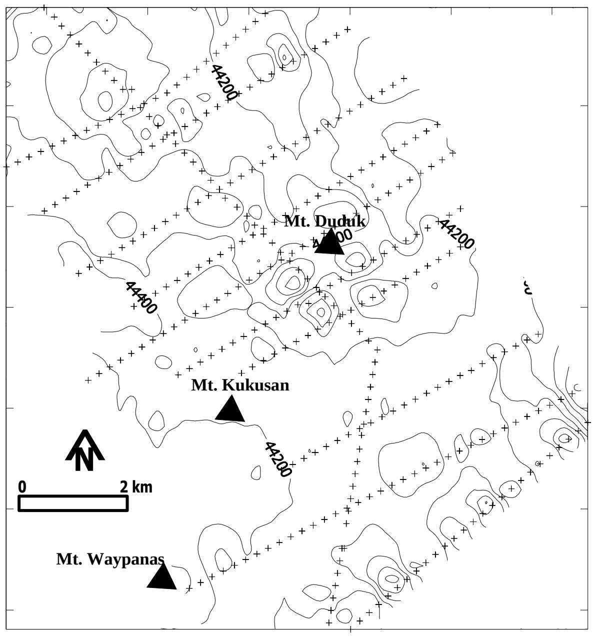

Figure 1. The residual Bouguer anomaly over the Ulubelu geothermal system. Contour values are in mGal. The coordinates are given in terms of the Indonesian map (m) standard metric grid referred to as Dittop TNI-AD (1980).

A terrain density estimate was made by Suharno (2003) using the Nettleton method (Dobrin and Savit, 1988). The density estimated profile shows that the correlation of gravity with topography along this line can be matched by a value for terrain density of about 2.70 x 10^3 kg m^{-3}. Combined with the results from the laboratory measurements of borehole samples, this suggests that the overall mean density of rocks in the study area is close to 2.67 x 10^3 kg m^{-3}. This is also the mean density of upper continental crust commonly used for the reduction of Bouguer anomalies (Dobrin and Savit, 1988). The 2.67 x 10^3 kg m^{-3} value is adopted for the reduction of Bouguer anomalies.

3.3 Gravity Modeling Result

The gravity modeling results are represented in Figures 2–9. The models indicate the distribution of the permeability in the geothermal system based on the gravity anomalies.

Figure 2, shows the three dimensional model of the study area facing south-west. Figure 3, shows the model facing south-west, crossed at Northing 94100162. It indicates that the permeable area (blue color) is associated with the caldera or graben.

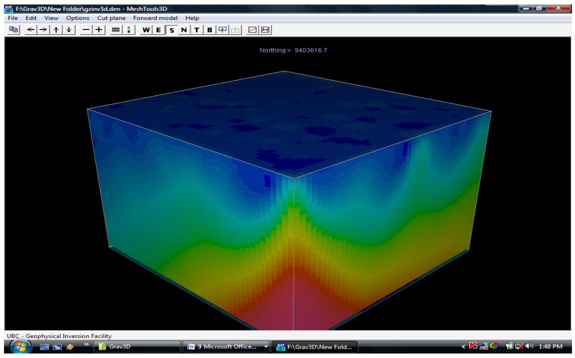

Figure 2. Three dimensional full body model facing south-west.

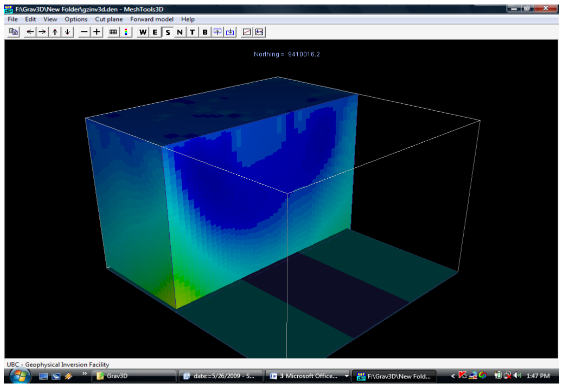

Figure 3. Three dimensional body model facing south-west, cut at Northing 94100162.

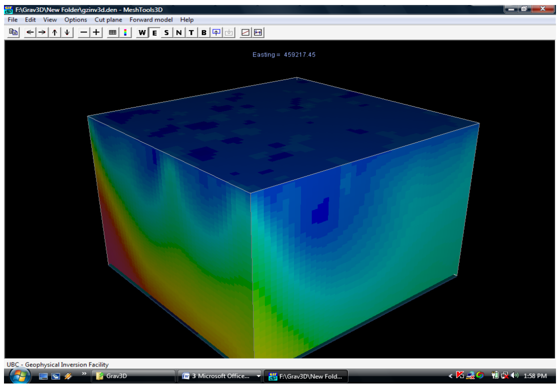

Figure 4. Three dimensional full body model facing south-east.

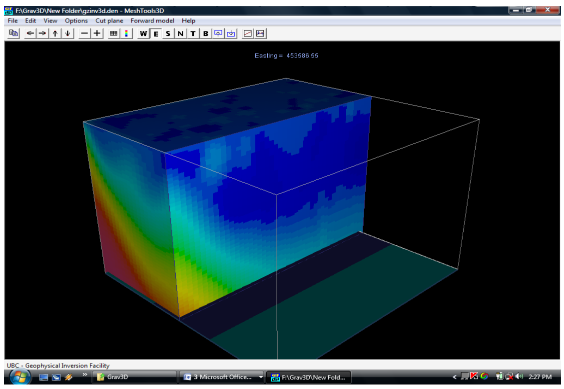

Figure 5. Three dimensional body model facing south-east, cut at Easting 453586.

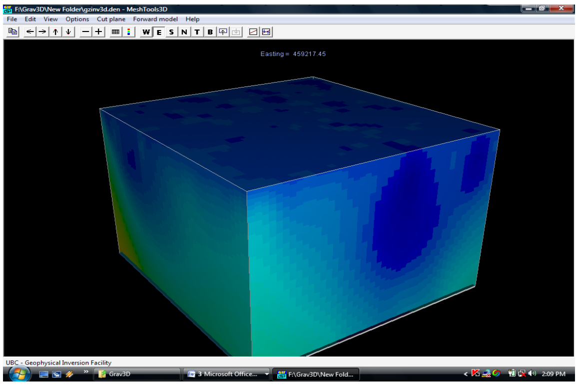

Figure 6. Three dimensional full body model, facing north-east.

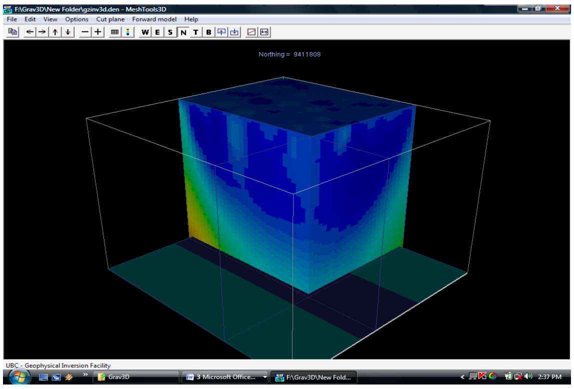

Figure 7. Three dimensional body model, facing north-east, cut at Easting 454125 and Northing 9411808.

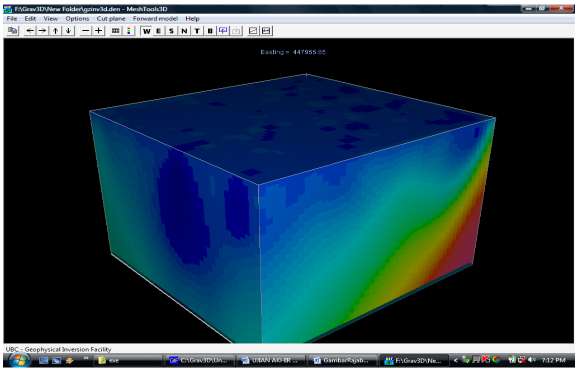

Figure 8. Three dimensional full body model facing north-west.

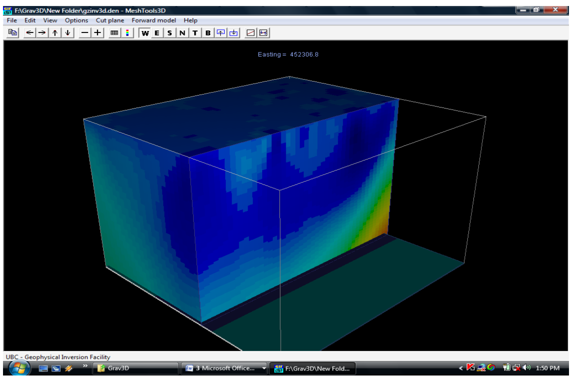

Figure 9. Three dimensional body model facing north-west, cut at Easting 452307.

Figure 4, shows the three dimensional model of the study area facing south-east. Figure 5, shows the model of the study area facing south-east, cut at Easting 453586. It indicates that the permeable area (blue color) is associated with the fault at the southern part and spreads out to the north.

Figure 6, shows the three dimensional model of the study area facing north-east. Figure 7, shows the model facing north-east, crossed at E: 454125, N: 9411808. It indicates that the permeable area is the surrounding Mt. Duduk. The summit of the Mt. occurs in the center of the Ulubelu caldera or graben. It indicates that the permeable zone is associated with the caldera or graben

Figure 8, shows the three dimensional model of the study area facing north-west. Figure 9, shows the three dimensional model facing north-western, cut at Easting 452307. It indicates that the permeable area (blue color) is associated with the fault at the southern part and spread out to the northern part, beyond to the cut-off gravity data. Based on Figures 9 and 5, the permeable zones extend to the north, out beyond the study area.

3.4 Qualitative interpretation

The residual anomalies (Figure 1) are negative in the northwestern but positive in the southwestern parts of the study area. This indicates that, in general, rocks surrounding Mts. Kukusan and Waypanas are denser than those in the area near Mt. Duduk. The low Bouguer anomalies around Mt. Duduk have been described by Suharno (2000) as due to the Ulubelu caldera being filled with low-density volcanic rocks.

The presence of broad negative residual anomalies in the northwest covering Mt. Rendingan lavas and pyroclastics suggests that these rocks have negative density contrasts with respect to the reference density of 2.67 x 10^3 kg m^{-3} (Suharno, 2003). The Mt. Rendingan pyroclastics consist of rhyolitic tuff seen in thin section. Negative anomalies also cover Mt. Kabawok pyroclastics, which mainly consist of andesite and dacite tuffs.

The positive residual anomalies in the southwestern sector appear to be related to the Mt. Kukusan basaltic andesite lavas. The highest anomaly, over Mt. Waypanas, is possibly associated with blocks of lava that accumulated around this mountain. The steep gradient of the anomalies on the exposure of low density Ranau formation (QTr) suggests that it is probably only a thin layer overlying the Mt Kukusan lavas (Suharno, 2003).

4. SUMMARY

The gravity model shows that the caldera or graben and permeable area occur across the Ulubelu geothermal system.

The distribution of the permeable zones indicated by the gravity data can be described as follows:

(1) Figures 2 and 3, show that the permeable area is associated with the caldera or graben.

(2) Figures 4 and 5, show that the permeable area is associated with the fault at the southern part and spreads out to the north.

(3) Figures 6 and 7, indicate that the permeable zone is associated with the caldera or graben.

(4) Figure 8 and 9, show that the permeable area is associated with the fault at the southern part and

spreads forward to the northern part, beyond the study area.

(5) Based on the Figures 9 and 5, the permeable zones extend to the north, beyond the of the study area.

5. ACKNOWLEDGEMENT

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