Mapping the Seulimeum Fault System in Krueng Raya, Aceh Besar (Indonesia) Using Gravity Surveys

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ABSTRACT

The gravity method is a nondestructive geophysical technique that measures differences in the earth's gravitational field at specific location. The purpose of this study is to map the Seulimeum fault system in Krueng Raya, Aceh Besar (Indonesia) by employing gravity surveys. The gravity survey was performed using CG5 AutoGrav Scintrex and the spacing between stations was 200-500 m randomly. The gravity data was processed by utilizing Microsoft excels and Surfer8 software which was displayed in a form of contouring and revealed fault zones. The local gravity value covers -33 to 21 mGal. The gravity results shows the trend pattern of low gravity value at northwest part and high gravity value at south-east part of Krueng Raya which was indicated as fault system. Geophysical results and geologic mapping indicated that the area is bounded by major faults.

KEYWORDS: Gravity, Seulimeum fault, Krueng Raya, Aceh Besar

INTRODUCTION

Gravity measurements are used to detect geological formations with different densities. The density contrasts leads to a different gravitational force which is measured in mGal or 10^{-3} cm/s^2. Density of the rocks mainly depends on the composition and porosity, but partial saturation of the rocks may also influence the values. Generally, sedimentary rocks are lighter than crystalline rocks. The raw data needs to be corrected for several factors. The results are usually presented in

Bouguer maps based on the Bouguer anomaly (Δg_B) where corrections have been done on the measured value (g_M) for tidal effects, elevation, local topography, latitude and drift for the gravimeter (Georgson, 2009).

SUMATRA FAULT ZONE

Fault zone is an area in the earth crust located at the boundary of two tectonic plates. A movement of the rocks and plates at fault zone usually induces earthquakes. Minerals are the building blocks of rocks. They are non-living, solid and like all matter, it's made of atoms of elements. Minerals form through natural processes within the earth, including volcanic eruptions, precipitation of a solid out of a liquid, and weathering of pre-existing minerals (Tunell et al., 1928). By identifying the minerals present in a given rock, geologists can begin to understand the history of the rock. Krueng Raya is located in Banda Aceh district which is one of the areas affected by tsunami disaster and precisely at the line of Sumatran fault system. The Sumatran fault zone (SFZ) is the most active fault in Indonesia as a result of strike-slip component of Indo-Australian oblique convergence. With the length of 1900 km, Sumatran fault was divided into 20 segments starting from the southernmost Sumatra Island having small slip rate and increasing to the north end of Sumatra Island as shown in Figure 1 (Prawirodirdjo et al., 2000). In this paper, gravity method was applied to the village of Krueng Raya, Banda Aceh (Indonesia). The gravity investigation, aimed to locate and map fault zones as critical steps in evaluating the earthquake potential of the region.

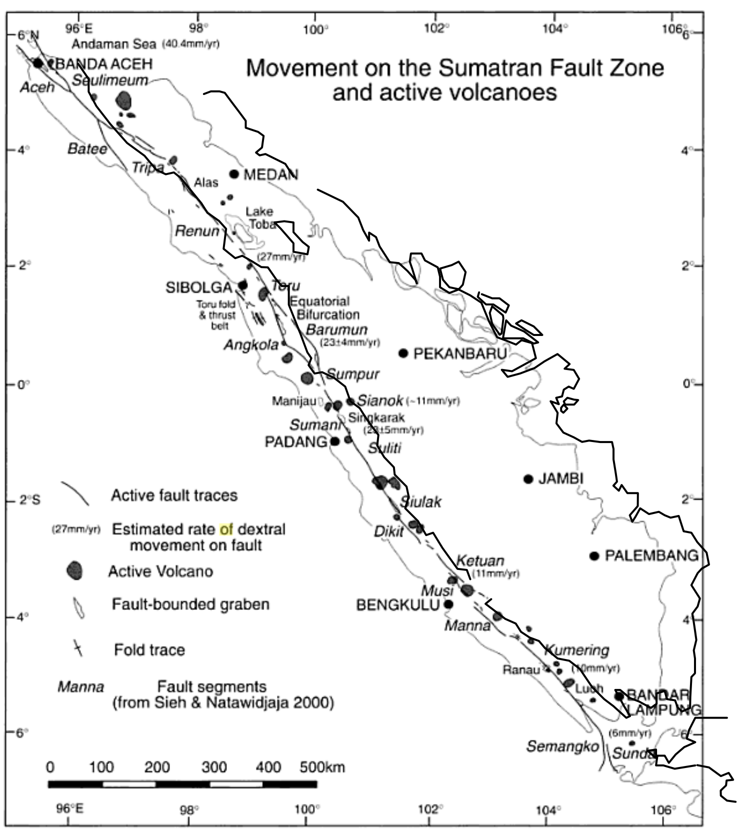

Figure 1: The great Sumatran fault zone (SFZ) is; a) a trench parallel, right-lateral strike-dip fault and b) divided into 20 fault segments.

GENERAL GEOLOGY

The regional geology of Banda Aceh Quadrangle has been mapped by Bennet et al., 1981 (Figure 2). The Krueng Raya lithology is dominated by Lam Tuba volcanic, composed of andesitic to dacitic volcanics, pumiceous breccia, tuffs, agglomerate and ash flows which intruded of the Seulimeum formation composed of tuffaceous and calcareous sandstones, conglomerates and minor mudstones (Bennet et al., 1981). The prospect area is near the Raya mount and Ie Seu'uem hotspring. It forms a topographic depression, occupied by alluvial flat and low, flat-topped hills within the Barisan range; a rugged mountain range that runs along the entire western edge of the Sumatera Island. Following closely the crest of the Barisan range is a continuous system of axial valleys, including the Kr. Tangse valleys, which marks the outcrop of the main fault line of the Sumatran fault system. This is essentially a right lateral fracture system (Katili and Hehuwat, 1967; Page et al., 1979). The area is controlled by two main faults system, with orientation NW to SE. The topographic morphology of the Krueng Raya is subdued because the rocks are strongly fractured and altered.

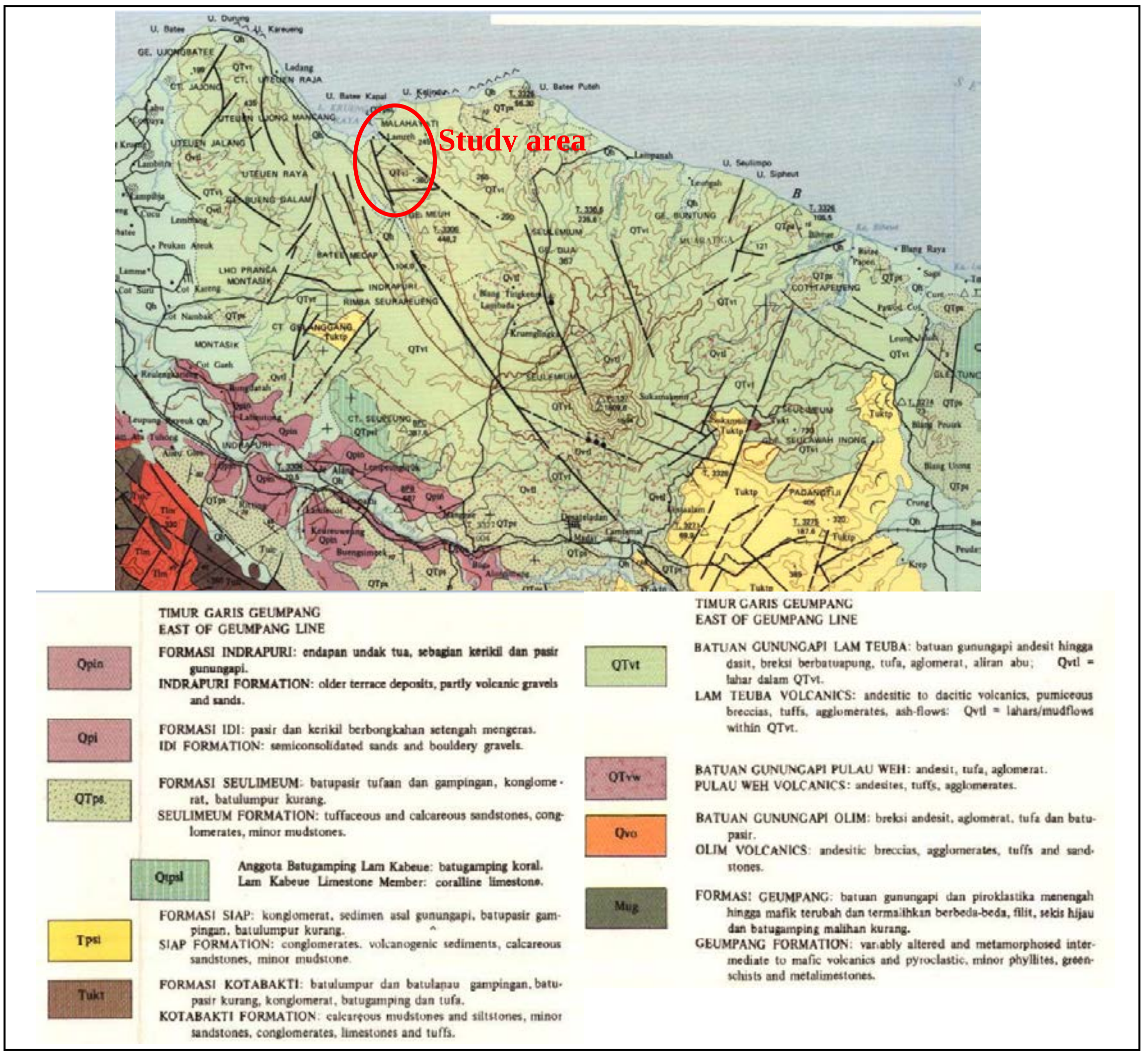

Figure 2: Geology map of the study area.

STUDY AREA

The study was carried out in the area of Krueng Raya, Banda Aceh (Indonesia) with area of 6 km x 8 km (Figure 3). The gravity survey was carried out with random moving station. The distance was set at 200-500 m to cover the survey area (Figure 4).

Figure 3: The gravity survey at Krueng Raya, Banda Aceh (Indonesia).

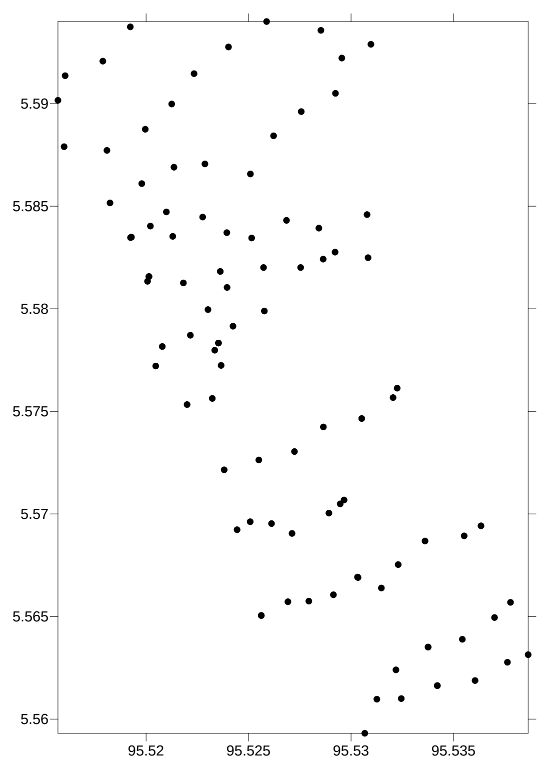

Figure 4: Gravity stations of Krueng Raya area.

METHODOLOGY

The gravity measurement was applied at all moving station scattered around the study area with station interval of 200-500 m, in order to identify subsurface structure. A local base station was located at one place where one repeats a gravity reading in the morning and in the afternoon after finishing survey line for each day. The repeated readings are performed because even the most stable gravity meter will have their reading drift with time due to elastic creep within the meter's springs and also to help remove the gravitational effects of the earth tides. The instrument drift is usually linear and less than 0.01mGal/hour under normal operating conditions. The gravity survey covered most of the area, except some locations due to thick jungle.

The observed gravity readings obtained from the gravity survey reflect the gravitational field due to all masses in the earth and the effect of the earth's rotation. To interpret gravity data, one must remove all known gravitational effects not related to the subsurface density changes. These include latitudinal variations, elevation changes, topographic changes, building effects and earth tides (LaFehr, 1991). The field survey usually removes the earth tidal effect during the drift curve determination and use latitudinal correction. To take into account, the vertical decrease of gravity with increase of elevation from a predetermined datum plane (usually sea level) and the gravitational field of the mass between the datum plane and a gravity station, a free-air and Bouguer corrections are applied to the observed gravity data. The Bouguer correction requires an average density value (Bouguer reduction density) of the mass, which is usually assumed to be 2.67 gm/cm^3. The final form of the processed gravity data is called a complete Bouguer gravity anomaly. Once corrections were done, the data were exported into a grid file to the Surfer8 software to perform gravity contour map.

RESULTS AND DISCUSSION

Figure 5 shows the bouguer anomaly contour map. It consists of two gravity anomalies which may be related to the Seulimeum fault where it is located at northwest part and south-east part. The local gravity values cover -33 to 21 mGal. The low values are distributed on the northwest part while the high values are distributed on the south-east part. Figure 5(b) shows the lateral view of the faulting system which runs from northwest to south-east in the study area. The Bouguer anomaly contour map shows the same trend as geological map based upon Bennet et al. (1981) as it bends slightly to the west-east.

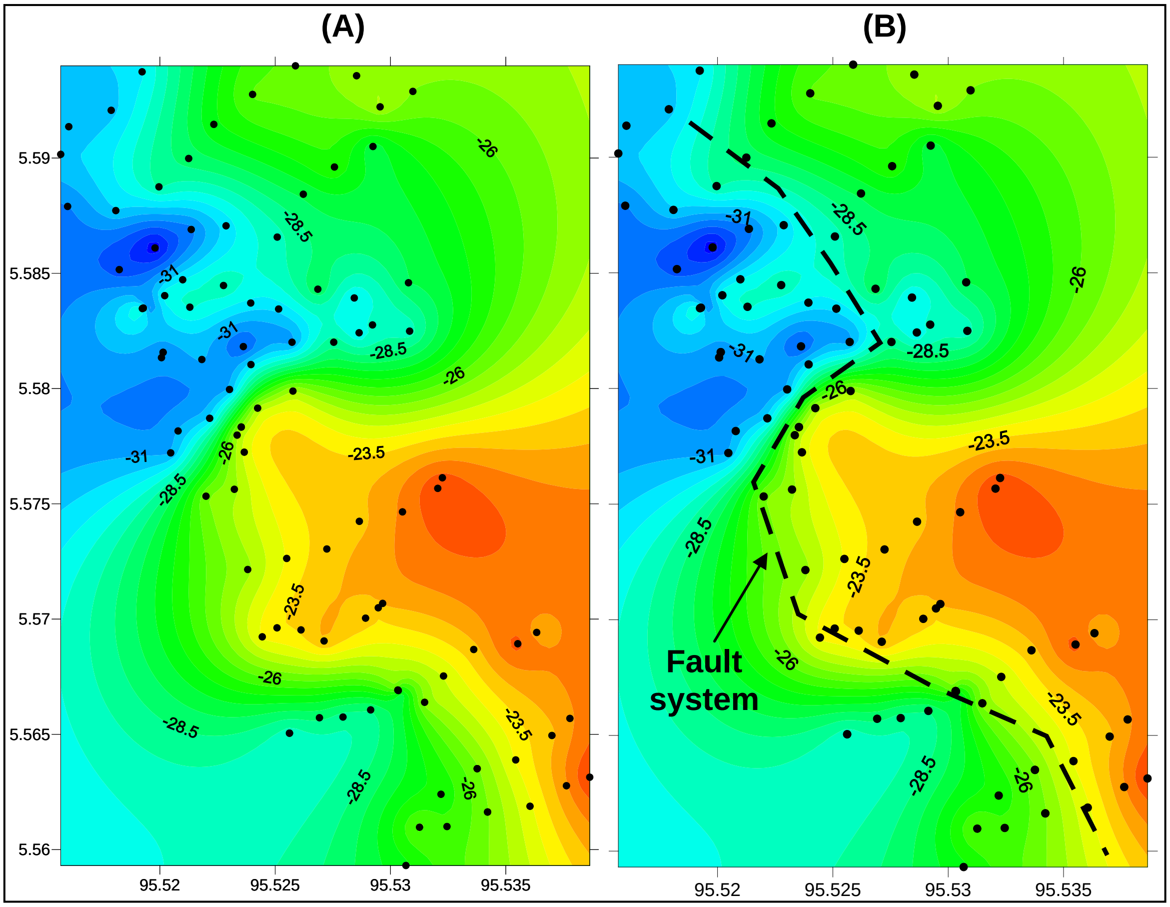

Figure 5: Bouguer anomaly map of Krueng Raya; a) local gravity b) fault system.

CONCLUSSION

Data collection, processing, contouring and interpretation of the gravity data provide increased understanding of the shallow structures associated with the Seulimeum fault system. The gravity results supported with geological map suggested the existence of several small fault plains in the study area. It is clear that the main trend of the Seulimeum faults in Krueng raya is in the NW-SE direction. The application of gravity survey can be easily determine the fault zones as well as the subsurface characterization of the study area.

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REFERENCES

1. Bennet, J. D., McC, D., Bridge, Cameron, N. R., Djunuddin, A., Ghazali, S. A., Jeffrey, D. H., Kartawa, W., Keats, W., Rock, N. M. S., Thomson, S. J. and Whandoyo, R. (1981) “Geologic map of the Banda Aceh Quadrangle, Sumatra”.

2. Georgson, L. S. (2009) “ Geophysical Methods Used In Geothermal Exploration,” Presented short course IV on Exploration for Geothermal Resources, organized by UNU-GTP, KemGen and GDC, at Lake Naivasha, Kenya, November 1-22, 2009.

3. Katili, J., and Hehuwet, F. (1967) “On the occurrence of large transcurrent faults on Sumatra Indonesia: Osaka, Japan”, *Osaka City University Journal of Geoscience*, Vol. 10, pp 1-17.

4. LaFehr, T. R. (1991) “Standardization in gravity reduction”, Geophysics, Vol 56, pp 1170-1178.

5. Page, B. G. N., Bennett, J. D., Cameron, N.R., Bridge, D., McC Jeffery D. II., Keats, W. and Thaib, J. (1979) “A review of the main structural and magmatic features of northern Sumatra,” *Journal of Geological Society of London*, Vol. *1*, 36, pp 569-579.

6. Prawirodirdjo, L., Bock, Y., Genrich, J. F., Puntodewo, S. S. O., Rais, J., Subarya, C., and Sutisna, S. (2000) “One century of tectonic deformation along the Sumatran fault from triangulation and Global Positioning System surveys,” *Journal of Geophysical Research*, Vol. 105, No. 28, pp 343–28, 363.

7. Tunell, George, and Posnjak, E.W. (1928) “Studies of Weathering and Sedimentation,” Carnegie Institution of Washington, Yearbook No. 27, pp 71-76.