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EXPLORING SEULIMEUM FAULT IN ACEH, INDONESIA USING MAGNETIC METHOD

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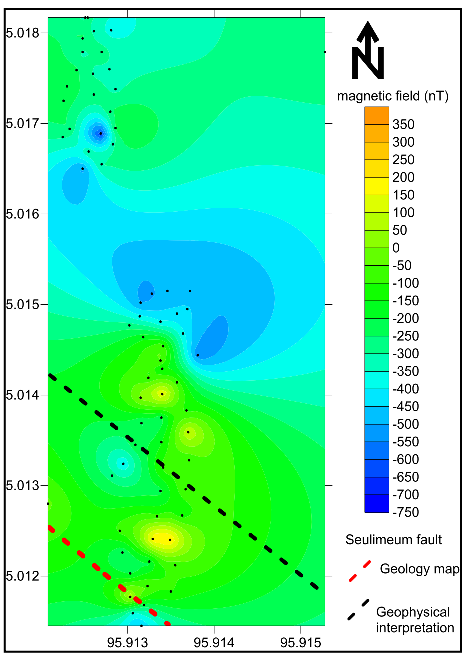
Graphical abstract



Abstract

The study explores the use of magnetic method as an alternative measurement device for Seulimeum fault detection and location in Krueng Raya, Ie Seu Um, Iejue, Lamtamot (Aceh Besar) and Tangse, Pidie (Indonesia). The magnetic survey was performed using G-856 proton magnetometer and the spacing between stations was depends on the study location; Krueng Raya (50-300 m spacing randomly), Ie Seu Um (10-30 m randomly), Iejue (50 m), Lamtamot (50-70 m) and Tangse (50-200 m). The magnetic data was processed by utilising Microsoft excels and Surfer 10 software which was displayed in a form of contouring and revealed fault zones. The local magnetic value in Krueng Raya was -700 to 650 nT, Ie Seu Um was -500 to 300 nT, Iejue was -150 to 600 nT, Lamtamot was -200 nT to 200 nT and Tangse was -750 to 350 nT. The magnetic results showed the trend pattern of low and high residual value surround the study area. The highly contrast of magnetic contouring map was interpreted as fault zones. All results show that the trend pattern of fault mapped by magnetic method was trending from northwest to southeast direction. The magnetic residual map was correlated with geological map which show the existence of Seulimeum fault and proved that the study area is bounded by small faults.

Keywords: Magnetic; fault; Krueng Raya; Ie Seu Um; Iejue; Lamtamot; Tangse; Seulimeum; Aceh

Abstrak

Kajian meneroka menggunakan kaedah magnetik sebagai peranti pengukuran alternatif bagi pengesanan sesar Seulimeum dan lokasi terletak di Krueng Raya, Ie Seu Um, Iejue, Lamtamot (Aceh Besar) dan Tangse, Pidie (Indonesia). Kajian magnetik dijalankan menggunakan proton magnetometer G-856 dan jarak antara stesen bergantung pada kawasan kajian; Krueng Raya (50-300 m secara rawak), Ie Seu Um (10-30 m secara rawak), Iejue (50 m), Lamtamot (50-70 m) and Tangse (50-200 m). Data magnetik diproses menggunakan Microsoft excels dan perisian Surfer 10 yang dipamerkan dalam bentuk kontur dan mendedahkan zon-zon sesar. Nilai magnetik di Krueng Raya adalah -700 nT hingga 650 nT, Ie Seu Um adalah -500 hingga 300 nT, Iejue adalah -150 hingga 600 nT, Lamtamot adalah -200 nT to 200 nT dan Tangse adalah -750 hingga 350 nT. Keputusan magnetik menunjukkan corak aliran bagi sesar yang dipetakan menggunakan kaedah magnetik mengalir dari arah barat laut ke tenggara. Peta sisa magnetik dikorelasikan dengan peta geologi yang menunjukkan kewujudan sesar Seulimeum dan membuktikan bahawa kawasan kajian disempadani dengan sesar-sesar kecil.

Kata kunci: Magnetik, sesar, Krueng Raya, Ie Seu Um, Iejue, Lamtamot, Tangse, Seulimeum, Aceh

1.0 INTRODUCTION

Gravity method was conducted to identify any fault system (Seulimeum fault) in Krueng Raya, Aceh Besar (Indonesia) by utilising the difference of density exhibit from different material in the earth. The result with be correlate with the geological map and also to identify and understand the trend patterns or characteristics of the fault system based on the contrast of the bouguer anomaly contour map [1]. A base station is fixed at one place and the reading is taken at the beginning and at the end of each survey to reduce the observed gravity value. The study area of 3 km × 4 km is divided into 2 boxes of approximately same size. The interval spacing in the study area was 200-500 m randomly. The data is processed using the Microsoft Office Excel and Surfer8 software is used to map the bouguer anomaly contour map. The contour map shows that the lowest value of -33.5 mGal is in the northwest and the highest value of -21.5 mGal is in the southeast part of the area. Geological map of the area and the bouguer anomaly contour map is correlated and the Seulimeum fault system can be detected successfully using gravity method.

The Seulimeum fault system stretches from the northwest to southeast at the upper part of the area and bends towards southeast at the latitude of 5.583 of the Krueng Raya area. The fault has characteristic of low, intermediate and high bouguer anomaly contrast on the contour map. In this study, magnetic method was used to explore the Seulimeum fault in Aceh.

2.0 MAGNETIC METHOD

The magnetic method measures the intensity of the natural magnetic field [2], [3]. This includes contribution from the earth's core and crust, as well as any secondary magnetic field induced in magnetic geological bodies, which locally creates positive and negative magnetic field anomalies. Those anomalies are the target of a magnetic survey for geological purposes [4,5]

3.0 GEOLOGICAL AREA

The regional geology of Banda Aceh Quadrangle has been mapped by [6] (Figure 1). The Krueng Raya lithology is dominated by Lam Tuba volcanic composed of andesitic to dacitic volcanic, pumiceous breccia, tuffs, agglomerate and ash flows which intruded of the Seulimeum formation composed of tuffaceous and calcareous sandstones, conglomerates and minor mudstones [6].

The prospect area is near the Raya mount and Ie se uem hot spring. 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 [7,8]. The area is controlled by two main faults system, with orientation NW to SE. The topographic morphology of the Krueng Raya [9,10] is subdued because the rocks are strongly fractured and altered. Tangse has Gle Seukeun complex which is composed of granodiorits, subordinate gabbros, diorite, biotitic granite and dyke rocks.

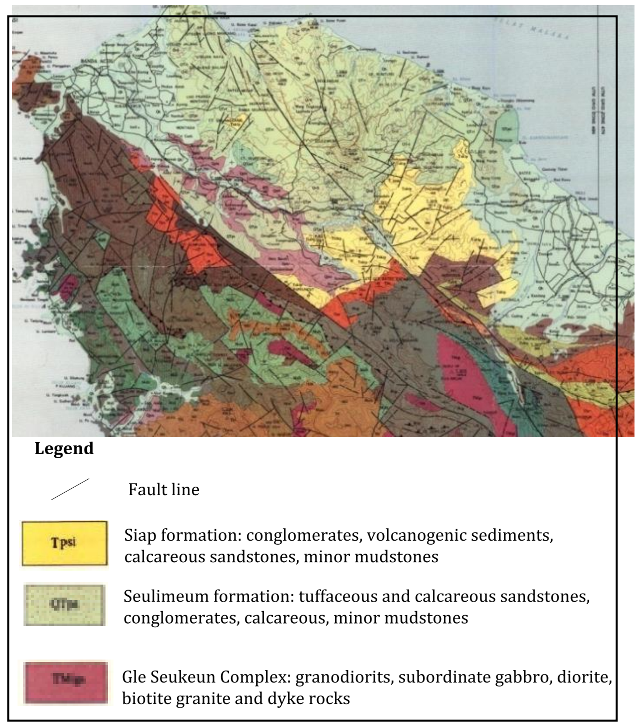


Figure 1 Geology map of Aceh, Indonesia [6]

4.0 STUDY AREA

In this study, magnetic survey was chosen as alternative measurement device for Seulimeum fault detection.

Krueng Raya (Banda Aceh) is one of the areas affected by tsunami disaster and precisely at the line of Sumatra fault system. Ie Seu Um area is located approximately 10 km from Krueng Raya. [11] A hot water spring can be found in Ie Seu Um which can be easily reached in one hour from Banda Aceh (Indonesia). Iejue is also a source of hot spring area. Lamtamot is located near to Seulawah Agam. In Aceh, there are some volcanoes that still active such as Seulawah Agam in Aceh Besar where it is located about 8 km from northwest of Lamtamot. This volcano provide heat source for Ie-Seu Um hot spring in Krueng Raya. Tangse is located in Pidie district and is one of the Seulimeum fault segment.

The Sumatra fault zone (SFZ) is the most active fault in Indonesia (right lateral strike-slip) with the length of

1900 km. Sumatra 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 2 [12].

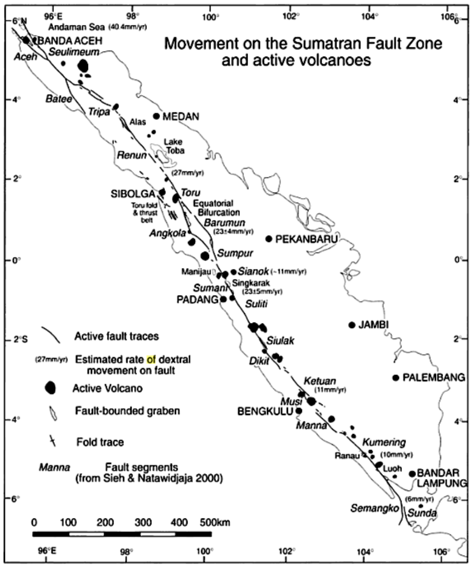


Figure 2 The great Sumatra fault zone (SFZ) [12]

The study was carried out in the area of Krueng Raya, Ie Seu Um, Ieju and Lamtamot (Aceh Besar) and Tangse (Pidie), Indonesia (Figure 3). The Krueng Raya area was covered about 6 km x 8 km. The distance was set at 50-300 m randomly to cover the survey area (Figure 4a).

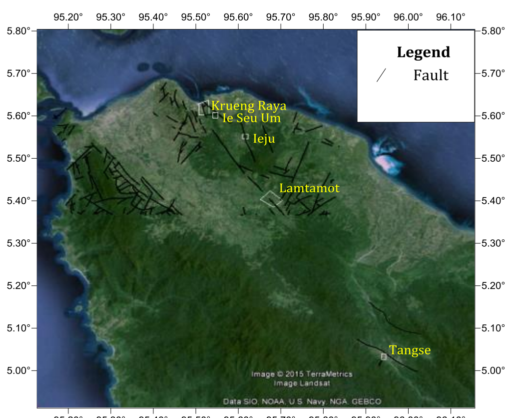


Figure 3 The location of study area in Krueng Raya, Ie Seu Um, Ieju and Lamtamot (Aceh Besar) and Tangse (Pidie), Aceh, Indonesia [13]

A hot water spring can be found in Ie Seu Um area approximately 10 km from Krueng Raya and 45 km from Banda Aceh (Indonesia) which can be easily reached in one hour. A magnetic survey was carried out with random moving station (10-30 m) to cover the survey area (Figure 4b).

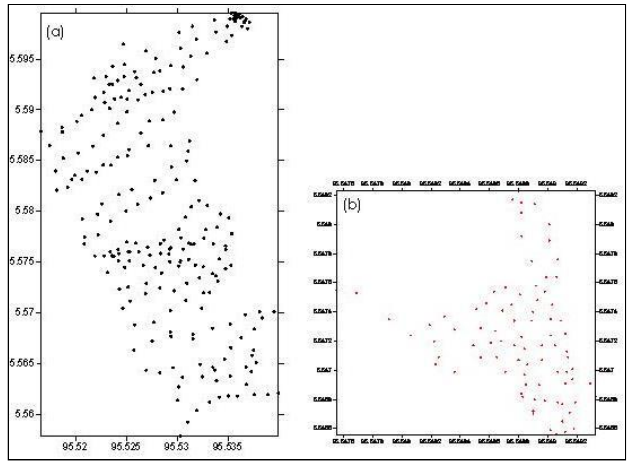


Figure 4 Magnetic stations: (a) Krueng Raya and (b) Ie Seu Uem area

Ieju area conducted with three different survey lines which were L1, L2 and L3 with length of 1 km and 50 m interval of each magnetic station. Lamtamot was located in Aceh Besar district at northern part of Sumatra land. The distance between Krueng Raya and Lamtamot is about 40 km. The magnetic spacing conducted in Lamtamot was 50-70 m randomly (Figure 5).

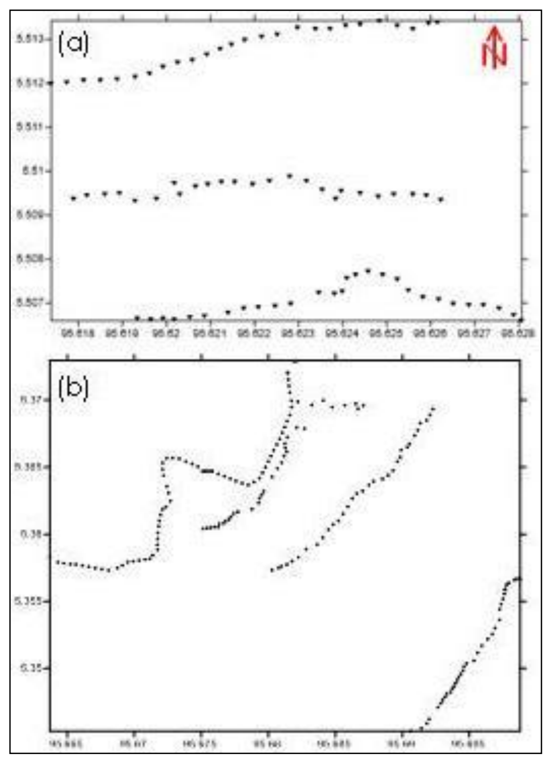


Figure 5 Magnetic stations: (a) Ieju and (b) Lamtamot area

Tangse was located in Pidie district at the centre part of Sumatra land. The magnetic spacing conducted in Tangse was 50-200 m randomly (Figure 6).

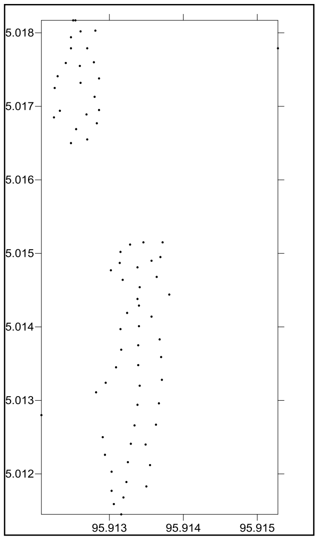


Figure 6 Magnetic stations of Tangse, Pidie, Aceh, Indonesia

5.0 METHODOLOGY

The magnetic method involves the measurement of the earth's magnetic field. The magnetic survey was carried out with scattered moving station in order to detect the subsurface structure. The used system is designed to measure the total field and/or gradient field, and is essentially proton precession devices. The measured independent grid was later combined to form a single master grid. The master grid provided a full magnetic map for easy display of the anomalies and allows the data to be processed using Surfer10 software. [14]

A base station with magnetic homogeneity was selected within the study area to record magnetic readings at a time interval of 1 minute to correct the diurnal variation effects of the earth's field from survey measurements. The magnetic survey covered most of the area, except some locations due steep slope and thick jungle in the area. Base station data was used to correct the moving data, and finally, a total intensity magnetic anomaly map was produced, reflecting the subsurface structure. Magnetic data alone gives a general idea about the subsurface structures affecting the study area. Processing the magnetic data enhances and sharpens the anomalies and trends of the data and helps in the interpretation.

In this work, two techniques were applied in order to estimate the locations of the subsurface faults. First step in magnetic processing was inspecting raw data for spikes, gaps, instrument noise or any irregularities in the data. The next step involved diurnal variation correction and IGRF correction to produce magnetic residual. Once corrections were done, the data were exported into a grid file to the Surfer10 software. After calculating a grid from xyz data in Surfer10, magnetic residual was carried out to compare the difference between a grid value and the new data at any definite location of the site. Finally, the magnetic results obtained from this survey will be correlated with geological map. The Seulimeum fault from the geological map was digitised and overlay in magnetic map to see the correlation between geophysical interpretations with the geological map.

6.0 RESULTS AND DISCUSSION

The data was plotted as a contour map using Surfer10 software and was displayed in nanoteslas (nT). The faults were interpreted if there was a possible highly magnetic contrast. The red dashed line was indicated as a Seulimeum fault.

Magnetic results show lateral view of the faulting system in the study area (Figure 7). The local magnetic value covers -700 to 650 nT (nanoTesla). The magnetic anomaly map of Krueng Raya, Banda Aceh (Indonesia) was characterized by low magnetic anomalies over northern part (-700 to -300 nT) and high magnetic anomalies (450 to 650 nT) spotted surrounding of the area, which interpreted as fault located at these parts. Potential faults location are depicted as linear northwest to southeast trending features due to the trend pattern of lower magnetic values than the surrounding (black dashed lines). Such value could due to the infilling of geological sediments such as breccias and gouge within the fault zone. From the magnetic maps, several of the anomalies can be clearly correlated with geological map.

The local magnetic value in Ie Seu Um, Aceh Besar (Indonesia) covers -500 to 300 nT. From the magnetic maps (Figure 8) several of the anomalies can be clearly correlated with geological surface expressions of volcanism such as fault with high magnetic anomalies (150 to 300 nT) over western part and low magnetic anomalies (-500 to -200 nT) over eastern part. From these map most of the hotsprings tend to lie in areas with intermediate magnetic anomalt with magnetic values of -150 to 250 nT. Geothermal exploration used magnetic measurement in order to trace the location of buried dykes and fault.

Figure 9 shows the magnetic results with lateral view of the faulting system in Ieju, Aceh Besar, Indonesia. The local magnetic value covers from -150 to 600 nT. The total intensity magnetic anomaly study area shows low magnetic value from -150 nT to -50 nT at northwest part while highly magnetic anomalies from range 200 to 450 nT at southeast of study area. The long dislocation from northwest part to southeast direction of study area is interpreted as geological fault (red dashed line).

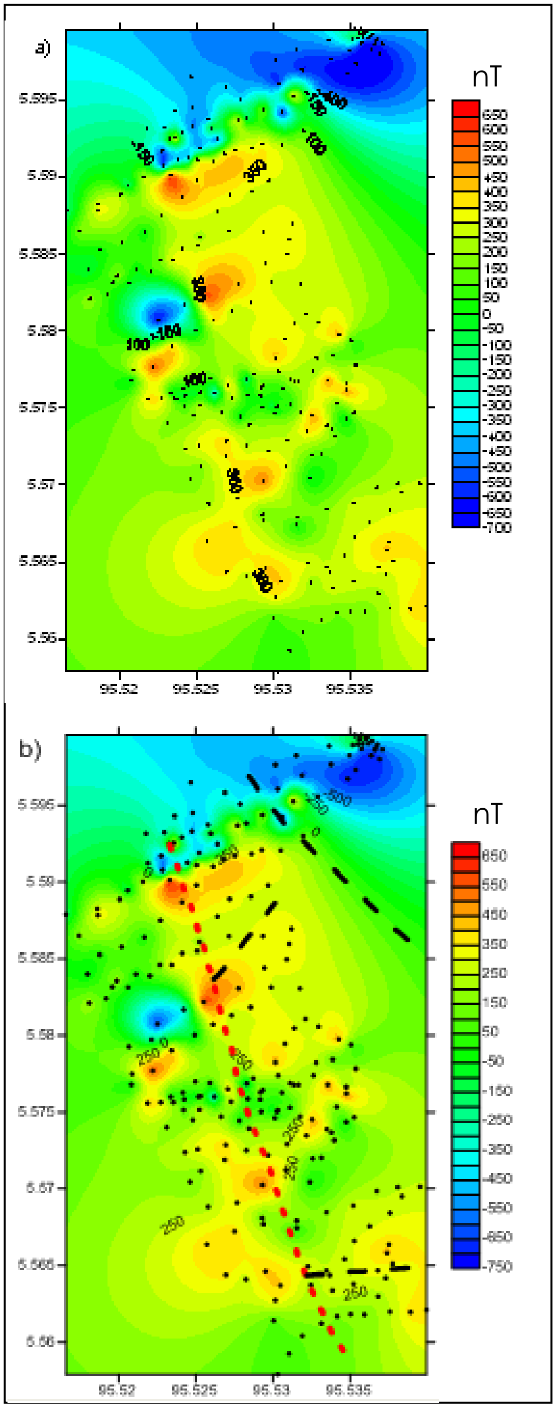


Figure 7 Magnetic anomaly in Krueng Raya: a) local residual and b) fault system

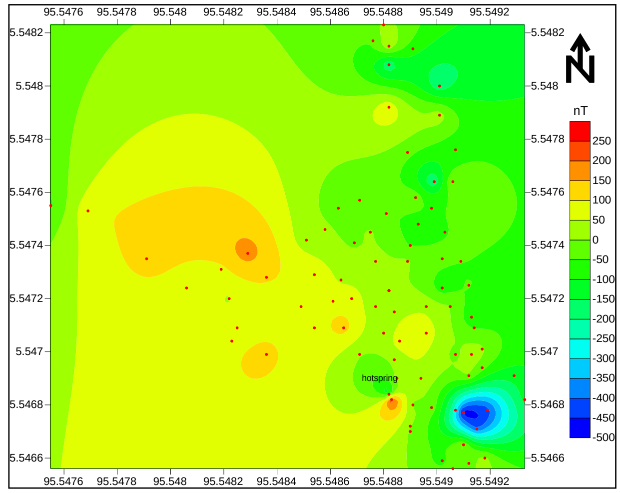


Figure 8 Magnetic anomaly in Ie Seu Um, Aceh Besar (Indonesia)

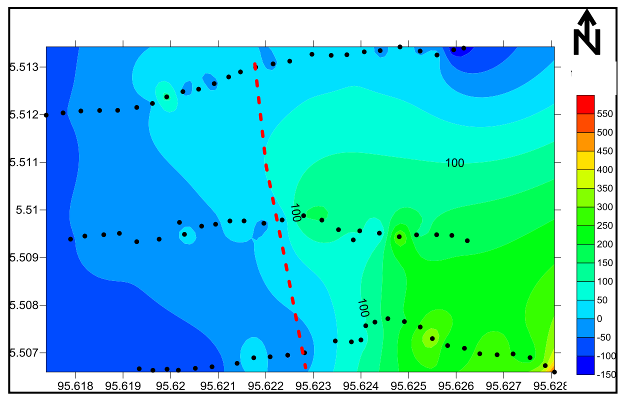


Figure 9 Magnetic anomaly of fault line system in Ieju

Based on the magnetic residual contour map in Figure 10, the result shows that the low magnetic anomalies assembled northwest southeast and high magnetic values assembled in northwest to southeast and northeast to southwest. The high magnetic anomalies almost break low magnetic anomalies into two parts. The local residual or magnetic values in this locality are covers around -200 nT to 200 nT. This study was clearly represented as a maximum magnetic closure from 100 to 200 nT surrounded by lower magnetic anomalies (-200 to -100 nT). Lamtamot area is occupied by alluvial flat and flat-topped hills within the Barisan Range where it form due to depression. Majority of the study area is characterized by low magnetic anomalies. Lamtamot is one of the Siap formation which is composed of conglomerates, volcanogenic sediment, calcareous sandstones and minor mudstones [15].

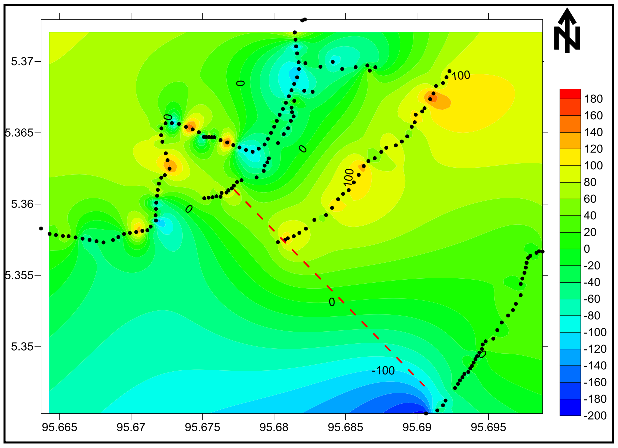


Figure 10 Magnetic anomaly of fault line system in Lamtamot

Figure 11 shows the result of magnetic contour map in Tangse, Pidie, Aceh, Indonesia. The low magnetic anomalies (-750 to -400 nT) assembled from west to east and high magnetic values (250 to 350 nT) was spotted at the lower part of the study area. The red dashed line shows the Seulimeum fault directed from northwest to southeast based on the geological map. The fault cannot be seen clearly due to the lack of magnetic stations in the study area. Based on the geophysical interpretation, the fault was located in the range of -200 to 100 nT (black dashed line).

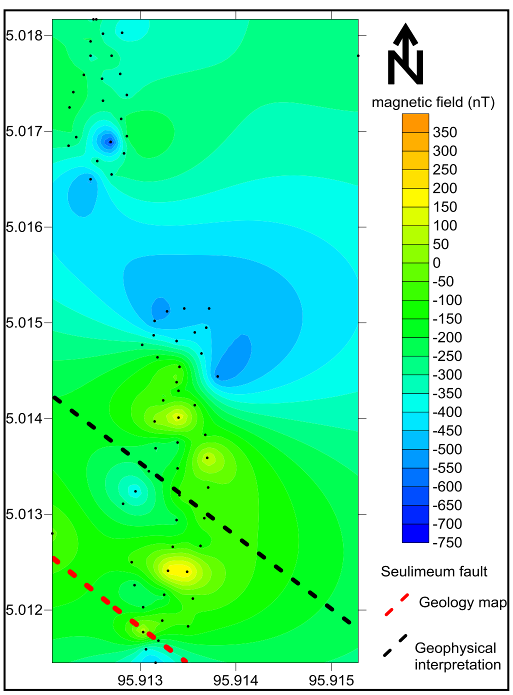


Figure 11 Magnetic anomaly of fault line system in Tangse

Table 1 shows the magnetic field values with the geological condition of each study area. The difference in magnetic field values between all the study areas is due to the different in geological condition. Even though Krueng Raya, Ie Seu Um and Ieju has the same type of rock (volcanic rock), the sediment composition of each location was different. However, the high and low magnetic values must be considered. This might be caused by the presence of fault that has been filled with sediments which reduce the intensity of magnetic field causes low magnetic response over the study area.

Table 1 Summary of magnetic field values with geological condition

Study area	Magnetic field (nT)	Low values (nT)	High values (nT)	Geology
Krueng Raya	-770 to 650	-700 to -300	450 to 650	Lam Teuba volcanic
Ie Seu Um	-500 to 300	-500 to -200	150 to 300	Lam Teuba volcanic
Ieju	-150 to 600	-150 to -50	200 to 450	Lam Teuba volcanic
Lamtamot	-200 to 200	-200 to -100	100 to 200	Alluvium
Tangse	-750 to 350	-750 to -400	250 to 350	Gle Seukeun complex

7.0 CONCLUSION

Data collection, processing, contouring and interpretation of the magnetic data provide knowledge and information associated with the Seulimeum fault system. The magnetic values vary with the geological condition at the study area. The magnetic 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, Ie Seu Um, Iejue, Lamtamot (Aceh Besar) and Tangse, Pidie (Indonesia) is in the NW-SE direction. The magnetic survey map was well correlated with the geological map. The application of magnetic survey can be easily determine the fault zones as well as the subsurface characterisation of the study area.

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