

# Magnetic Method Used In Geothermal Exploration in Ie-Seu 'Um, Aceh Besar (Indonesia)

## **Dr. Muhammad Syukri**

*Senior Lecturer, Geophysics Section, Department of Physics,  
Faculty of Sciences, Syiah Kuala University, Banda Aceh, Indonesia  
e-mail: m.syukri@unsyiah.ac.id*

## **Dr. M.M. Nordiana**

*Lecturer, Geophysics Section, School of Physics, 11800 Universiti Sains Malaysia,  
Penang, Malaysia  
e-mail: mmnordiana@usm.my*

## **Dr. Rosli Saad**

*Senior Lecturer, Geophysics Section, School of Physics, 11800 Universiti Sains  
Malaysia, Penang, Malaysia  
e-mail: rosli@usm.my*

## **Marwan**

*Lecturer, Geophysics Section, Department of Physics,  
Faculty of Sciences, Syiah Kuala University, Banda Aceh, Indonesia  
e-mail: marwan.fisika@gmail.com*

## **Nur Aminuda Kamaruddin**

*Postgraduate Student, Geophysics Section, School of Physics, 11800 Universiti  
Sains Malaysia, Penang, Malaysia  
e-mail: aminudakamaruddin@gmail.com*

## ABSTRACT

Magnetic method is one of the geophysical tools applied on the surface to explore geothermal resources. The study explores the use of the magnetic method as an alternative measurement device for geothermal detection and location in Ie-Seu 'Um, Aceh Besar (Indonesia). The magnetic survey was performed using G-856 proton magnetometer and the spacing between stations was 10 m to 30 m randomly. The magnetic data was processed by utilizing Microsoft excels and Surfer8 software which was displayed in a form of contouring and revealed geothermal zones. The local magnetic value covers -500 to 300 nT. The magnetic results showed low residual value at east part which was indicated as hot spring zones and high residual value at west part of Ie-Se 'Um. Effect of a geothermal reservoir at the area can be monitored using magnetic method.

**KEYWORDS:** Magnetic, Geothermal, Ie-Se 'Um, Aceh Besar

## INTRODUCTION

In volcanic areas, magma lies in shallow masses long after violent eruptions have stopped. The rocks above this magma remain hot. As a result, the water that filters down to these rocks gets super-heated to temperatures of over 200°C without boiling. This water is less dense than normal water. Where there is an unrestricted channel for it through the rocks, it rises to the surface to form hot-water pools. Often these hot-water pools have steam bubbling through them, forming hot springs. Therefore, hot springs are pools of super-heated water, connected to a hot underground source, with steam hissing and bubbling up constantly. Sulphurous fumes from the underground magma mixes with the water vapour and gives many of these geothermal features a strong smell of hydrogen sulphide (like rotten eggs). ([www.greenibis.com/edu/geo/frames/hotsprings.html](http://www.greenibis.com/edu/geo/frames/hotsprings.html)).

Different classifications can be based on total salinity, dominant chemical characteristics, temperature range, structural and stratigraphic environments, presence or absence of permeable reservoirs, and insulating cap-rocks.

There are two primary classifications of hot springs (Figure 1):

a) Filtration hot springs

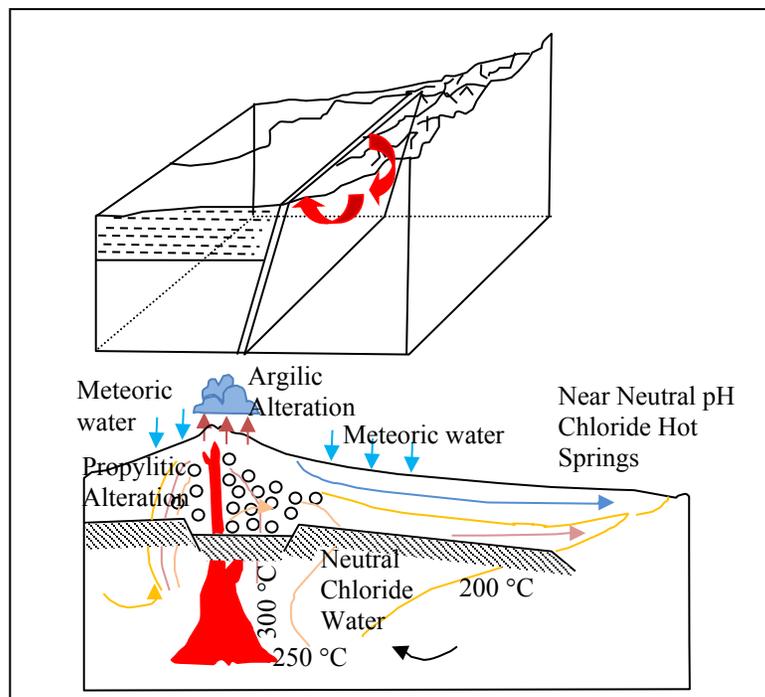
A filtration hot spring is a geothermally heated mineral water that is initially fed by rain water that seeps into the Earth through faults and fractures. As it travels into the Earth, it becomes subject to increased energy from natural geothermal heat, and is exposed to gases and an often wide variety of minerals from rock and mineral deposits. The water adsorbs the minerals via leaching, is heated by the geothermal heat source, and then returns to the Earth's surface.

b) Primary hot springs

A primary hot spring is a geothermally heated mineral water, where direct volcanic activity plays a far greater role in the process of the hot springs formation. One of the fundamental physical distinctions between a filtration spring and a primary spring is the mineral and gas content of the water, such as radon and bromide. Primary hot springs are often "powered" by magma chambers which exist miles under the Earth's surface, as well as in volcanically active regions. ([www.saratogaresortandspa.com/.../what-makes-a-mineral-hot-spring-a-m...](http://www.saratogaresortandspa.com/.../what-makes-a-mineral-hot-spring-a-m...))

## GENERAL GEOLOGY

The regional geology of Aceh Besar Quadrangle has been mapped by Bennet et al., 1981 (Figure 2). Lithology of this area is dominated by Lam Teuba volcanic composed of andesitic to dacitic volcanics, pumiceous breccia, tuffs, agglomerate and ash flows which intruded of the Seulimum formation composed of tuffaceous and calcareous sandstones, conglomerates and minor mudstones (Bennett et al., 1981). The prospect area is near the Raya mount and Ie-Se 'Um 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 island of Sumatra. 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 Sumatra 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 1:** Geothermal systems (After Henley and Ellis, 1983)

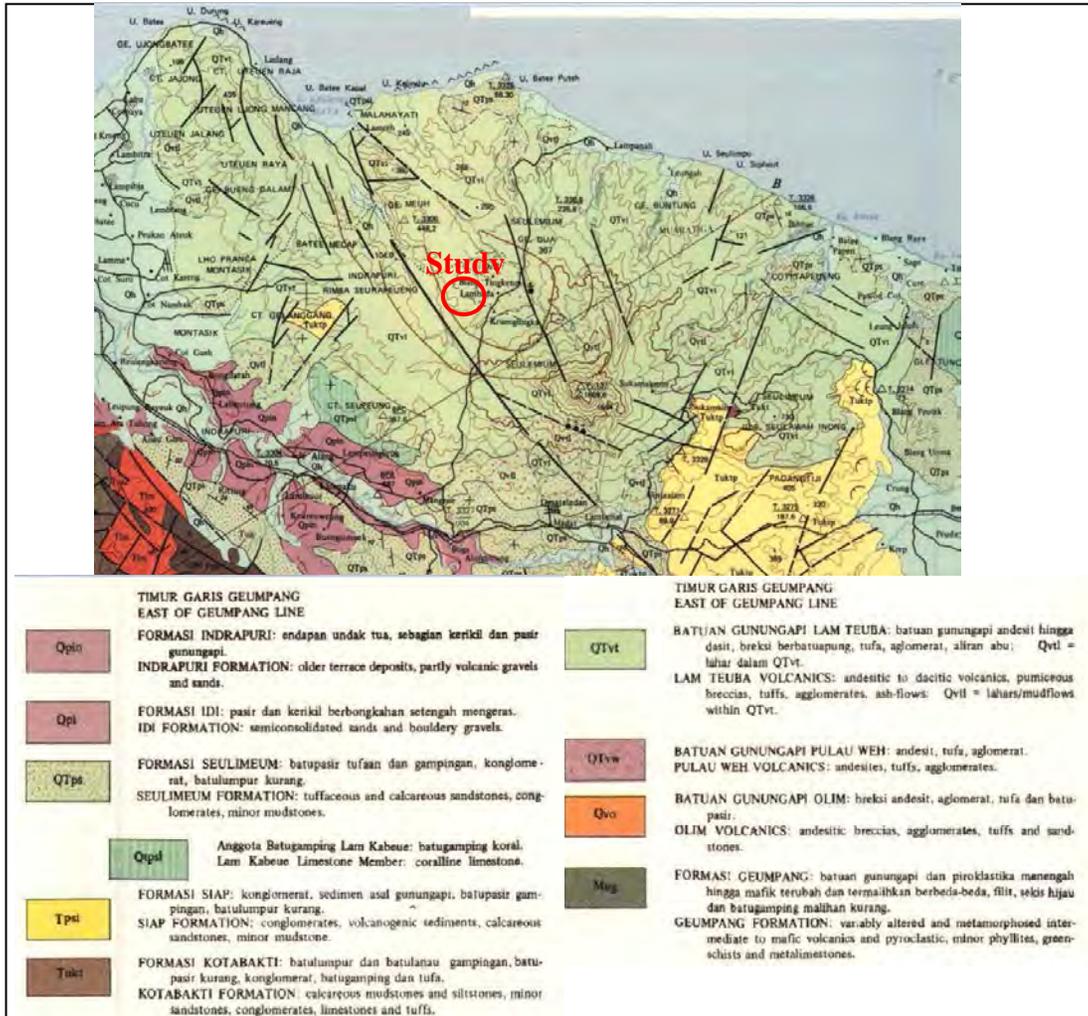


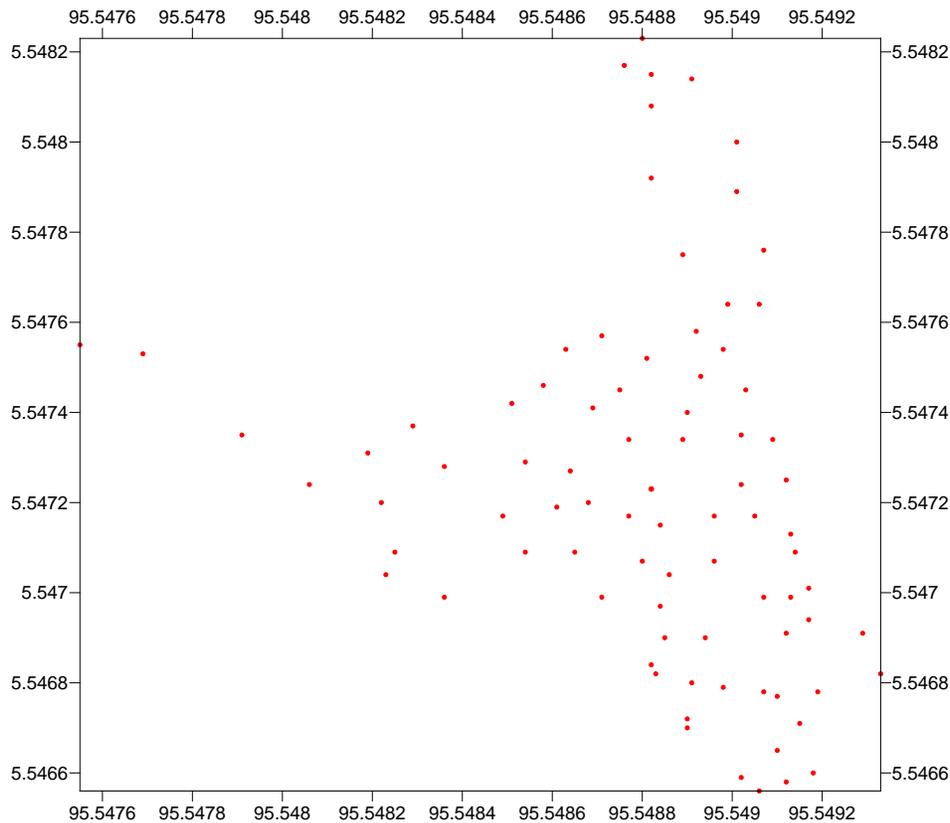
Figure 2: Geology map of the study area.

## STUDY AREA

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 (Photo 1). A magnetic survey was carried out with random moving station. The distance was set at 10 m to 30 m to cover the survey area (Figure 3).



**Photo 1:** Study area of magnetic survey at Ie-Seu 'Um, Aceh Besar (Indonesia).



**Figure 3:** Magnetic stations of Ie-Seu 'Um area.

## MAGNETIC METHOD IN GEOTHERMAL EXPLORATION

The magnetic method measures the intensity of the natural magnetic field. 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. . In general, the magnetic content (susceptibility) of rocks is extremely variable depending on the type of rock and the environment it is in. Common causes of magnetic anomalies include dykes, faults and lava flows.

Magnetic methods are widely used in geothermal exploration. Magnetisation of rocks is of two types:

- Induced magnetisation  $M_i$ , which has the same direction as the ambient earth's field; and
- Permanent magnetisation  $M_p$ , which often predominates in igneous rocks and depends upon their properties and history.

A magnetic anomaly is a local or regional disturbance caused by a change in the magnetisation. It is characterized by the direction and magnitude of the effective magnetisation and the shape, position, properties and history of the anomalous body. The magnetic field

strength is usually presented in  $\gamma$  (gamma) or nT (nanotesla). Magnetometers are fairly simple equipment and easy to use.

In geothermal exploration, magnetic measurements generally aim mainly at locating hidden intrusives and possibly estimating their depth, or at tracing individual buried dykes and faults. They may also aim at finding areas of reduced magnetization due to thermal activity. The measurements for local structures such as individual faults or dykes are done on the ground by regular measurements along parallel profiles or in a grid (Georgsson, 2009).

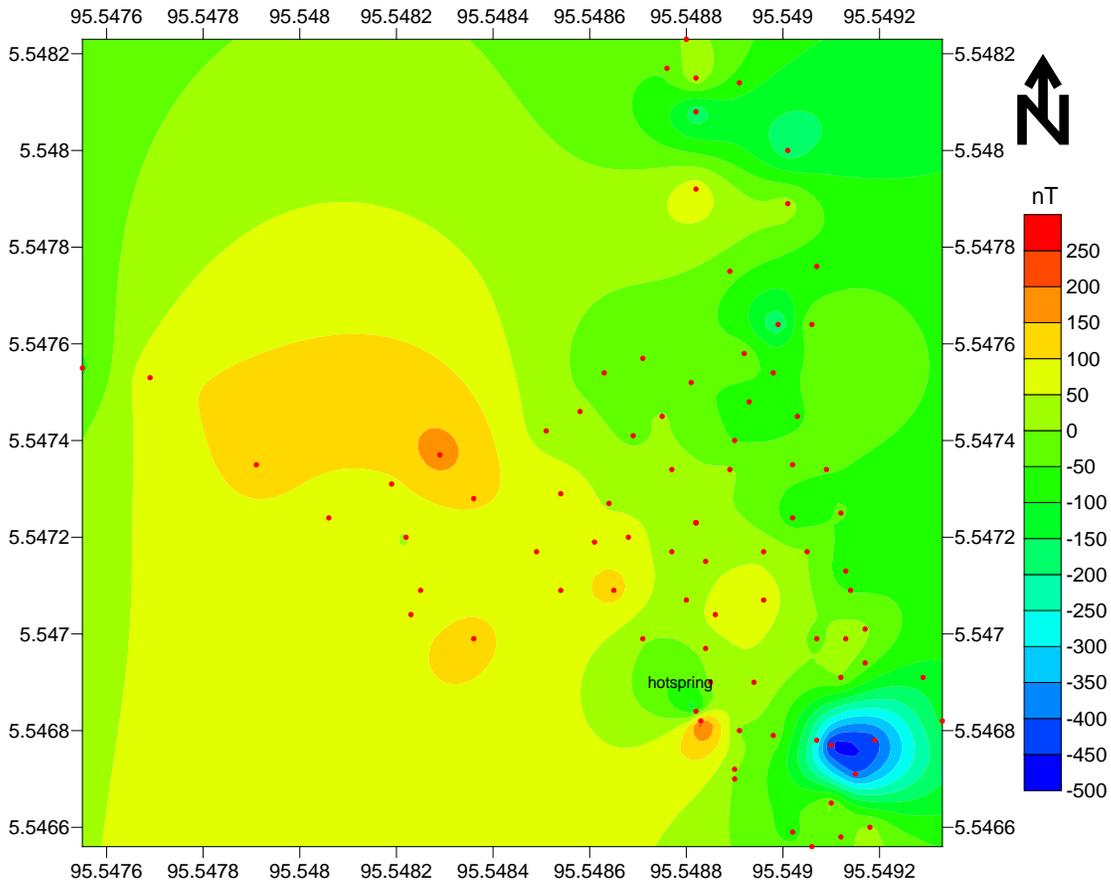
In a geothermal environment, due to high temperatures, the susceptibility decreases. It is not usually possible to identify with certainty the causative lithology of any anomaly from magnetic information alone. Interpretation of aeromagnetic anomalies over a geothermal area can be further complicated by the presence of magnetic effects caused by volcanic terrain, concealed lavas with a strong magnetisation or reversely magnetised rocks. Conversely, there are examples in the world (e.g., over Iceland) where hydrothermal demagnetisation causes distinctive negative magnetic anomalies over geothermal fields (Mariita, 2010).

## METHODOLOGY

The magnetic survey was carried out with scattered moving station with interval of 10 m to 30 m interval 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 Surfer8 software. A base station with magnetic homogeneity was selected within the study area to recorded 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, we will apply two techniques 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 Surfer8 software. After calculating a grid from xyz data in Surfer8, magnetic residual was carried out to compare the difference between a grid value and the new data at any definite location of the site.

## RESULTS AND DISCUSSION

The aim of a magnetic survey is to investigate the presence of a geothermal resource in Ie-Se 'Um, Aceh Besar (Indonesia). The local magnetic value covers -500 to 300 nT. From the magnetic maps (Figure 4) several of the anomalies can be clearly correlated with geological surface expressions of volcanism such as fault with high magnetic anomalies over western part and low magnetic anomalies over eastern part. From these map most of the hot springs tend to lie in areas with magnetic low (negative).



**Figure 4:** Magnetic anomaly in Ie-Seu 'Um, Aceh Besar (Indonesia).

## CONCLUSION

The magnetic method is capable of mapping the geothermal area. The NW-SE trending fault mapped by the magnetic measurements is believed to carry the water towards the geothermal field from the highlands. The result have provided important information for understanding of the geothermal system and location of hot spring and revealed possible new production for further study.

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