

Groundmagnetic survey used to identify the weathered zone, in Blang Bintang, Aceh, Indonesia

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Abstract. The objective of a geomagnetic survey is to investigate subsurface characteristic of geology, especially the weathered zone on the basis of the anomalies in the earth's magnetic field resulting from the magnetic properties of the underlying rocks. The magnetic properties of rocks called as magnetic intensity is extremely variable depending on the type of rock and the environment of the region. The result of the research shows that the local magnetic intensity varies of -697 nT and 484 nT in the study area 1 and about -697 nT and 103 nT in the study area 2 which are indicative of weathered zones. The weathered zones were interpreted by highly magnetic contrast. The total magnetic anomaly of Blang Bintang, Aceh Besar (Indonesia) shows higher magnetic anomalies over the eastern part (area 1) and low magnetic anomalies in the western part (area 2) of the study area, which indicate the presence of weathered zone due to the presence of sediments such as clay, gravel and schist within the zone. The study has shown that magnetic method could be used as an efficient tool for delineating weathered zone in a study area.

1. Introduction

Geophysical techniques are often significant for discovering unknown subsurface conditions. Magnetic method is the oldest geophysical technique applied in studying subsurface characteristics to measure lateral variation in the magnetic field in igneous and metamorphic rocks. The magnetic survey technique generally involves the measurement of the earth's magnetic field intensity or vertical gradient of the earth's magnetic field. Anomalies in the earth's magnetic field are caused by induced or remanent magnetism. Magnetization of any structure is due to induction in the geomagnetic field and permanent magnetization (remanent) [1]; [2]. The earth's magnetic field is a vector measured by a magnetometer [3]. Geological structures, rocks, minerals, ore deposits and engineering geological structures have magnetic properties that differ by orders of magnitude rather than percentages [15]; [16]. Magnetic rocks contain various combinations of induced and remnant magnetizations that perturb the Earth's primary field [2]; [17]; [23]. Total field and gradient are the two common types of magnetic measurements [4]; [18]; [19]. Total field measurement responds to the total magnetic field of the earth, natural and cultural magnetics, and any changes caused by a target [20]; [21]; [22].

Magnetic survey is a rapid and low-cost technique representing one of the most widely used geophysical methods in terms of line length surveyed [5]. One of the main objectives of the magnetic method is to map the changes in the magnetization which are related to the distribution of magnetic minerals. The detection depends on the amount of the presented magnetic material and its distance to the sensor [6] [23]. This work is a study of geophysical characterization of weathered zone based on the anomalies of magnetic field variation. The location of the study area is shown in Figure 1. This study is important to analyze the landslides prone area, and disaster mitigation.



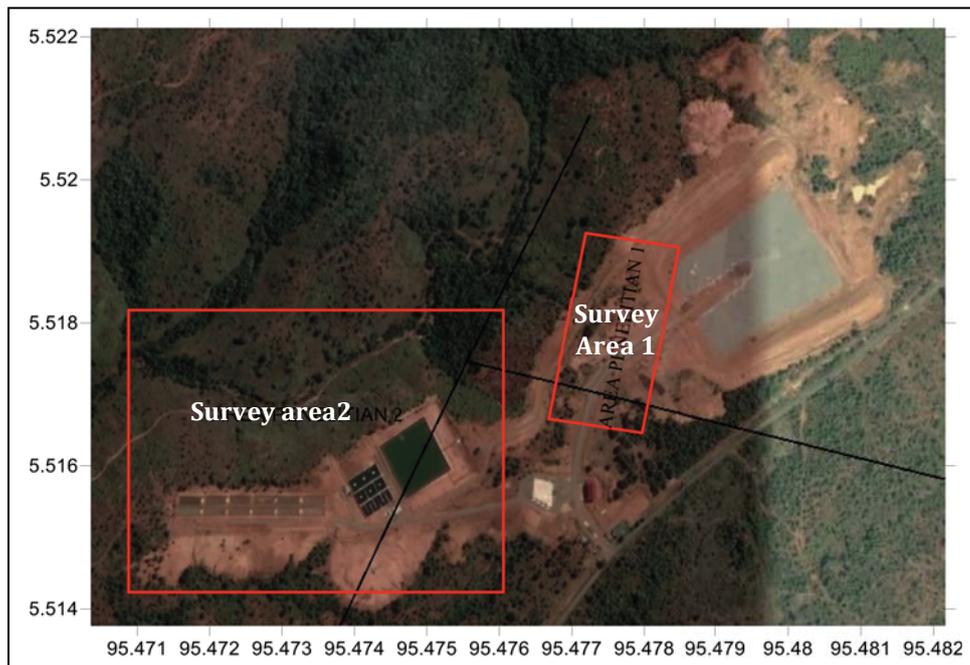


Figure 1. The study area of the magnetic survey in Blang Bintang, Aceh Besar (Indonesia).

Geological Setting

The geology of Aceh Besar Quadrangle has been mapped by Bennet [7] (Figure 2). The Blang Bintang valley is bounded by the Aceh Fault in the south-west and by the Seulimeum Fault in the northeast. The lithology of the Blang Bintang area is dominated by Lam Teuba volcanic composed of andesitic to dacitic volcanics, pumiceous breccia, tuffaceous, calcareous sometimes cross-bedded sandstones, conglomerates, agglomerate, minor mudstones and ash flows which intruded of the Seulimeum formation. The Seulimeum formation is composed of tuffaceous and calcareous sandstones, conglomerates and minor mudstones [7]. The Seulimeum Formation was deposited on the Pliocene to Pleistocene boundary. The adjacent Sumatra in the west coast constitutes volcanic arc with many Quaternary volcanoes such as Pulau Weh and Seulawah Agam. The volcanic belt is extended along the tectonically weak SFS and this tectonic weakness is supposed to have triggered volcanism [8]. In the northern most Sumatra, the Sumatran Fault System (SFS) splits into two major dextral strike-slip faults which are the Seulimeum and the Aceh Fault [7]. From upstream of the town of Jantho to downstream of the town of Indrapuri, the Pleistocene coarse-grained partly volcanic sands and gravels form a prominent terrace surface on both sides of the Krueng Aceh. Downstream of Indrapuri, the alluvial deposits can be subdivided into a shallow aquifer system and a deep aquifer system. Upstream of Indrapuri, the alluvial sandy-gravelly deposits in the vicinity of the river courses, the older terrace sand-gravel deposits and the semi-consolidated sandstones are assumed to constitute the main aquifers of the upper part of the Krueng Aceh valley [9].

To the northeast of the Aceh Fault, extensive Plio-Pleistocene volcanism is formed the area of the Seulawah Agam volcano. To the southwest the Aceh Fault builds a direct border to the highly structurally deformed Pre-Tertiary formations of the Barisan Mountains. The volcano is located within the Barisan Mountain Range which expands along the whole Sumatran west coast [10]. The survey area is close to the Krueng Raya mount and the Ie Se'uem hot spring. The tectonic setting of the area 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 [11]; [12]. The crest of the Barisan Range is a continuous system of axial valleys, including the Kr. Tangse valleys. This is essentially a right lateral fracture system [13]; [14]. The topographical morphology of the study area (Blang Bintang) is weak (soft) because the rocks are strongly fractured and altered.

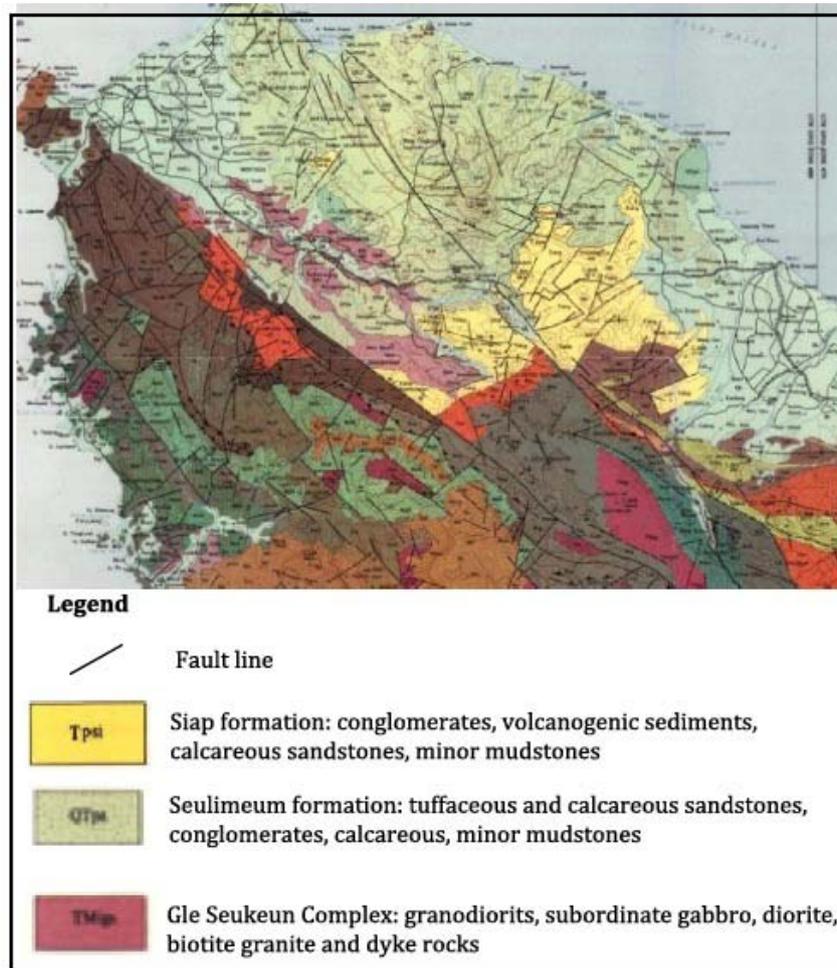


Figure 2. Geology map of study area [7]; [11].

2. Methods

The magnetic survey was carried out to understand the subsurface structures which could be the targets to investigate the potentiality of weathered areas. The magnetic survey of two study areas were conducted with scattered moving station ranging from 10 to 20 m in order to detect the subsurface structure. Measurements were taken using two units of portable G-856 proton precession magnetometer providing a standard resolution of 0.1 nT and 0.5 nT absolute accuracy. One unit was used as a base station to record automatically, every 60 seconds to correct the diurnal variations of the earth geomagnetic field from the measurements. Base station data was used to correct the moving data, and finally, a total intensity magnetic anomaly map was produced, reflecting the subsurface structure. The other unit was used to measure the total intensity of the magnetic field at each point of observations along the profiles. To obtain a representative reading, the sensor should be operated well above the ground. The proton magnetometer measures a radio-frequency voltage induced in a coil by the reorientation (precession) of magnetically polarized protons in soil containing water. No magnetic storms were recorded during the periods of measurements.

The data were presented as magnetic map by plotting the magnetic values against station separations for each traverse. Magnetic surface map (2D plot) were also constructed for a more qualitative interpretation using Surfer 10 software. Processing the magnetic data enhances and sharpens the anomalies and the trends of the data and helps in the interpretation. In this survey, two techniques were applied in order to estimate the weathered area. First step, the process was the inspection of raw data for spikes, gaps, instrument noise or any irregularities in the data. The second step involved

diurnal variation correction and IGRF correction to produce magnetic residual. Data are usually displayed in the form of a contour map of the magnetic field, but interpretation is often made on profiles.

3. Results and Discussion

Magnetic results show lateral view of the weathered zone in the study area (Figure 3). Magnetic survey data was plotted as a contour map using Surfer10 software and was displayed in nanoteslas (nT). The local magnetic intensity contrast observed between -697 nT and 484 nT at study area 1 and between -697 nT and about 103 nT at study area 2 which are indicative of probable weathered zones.

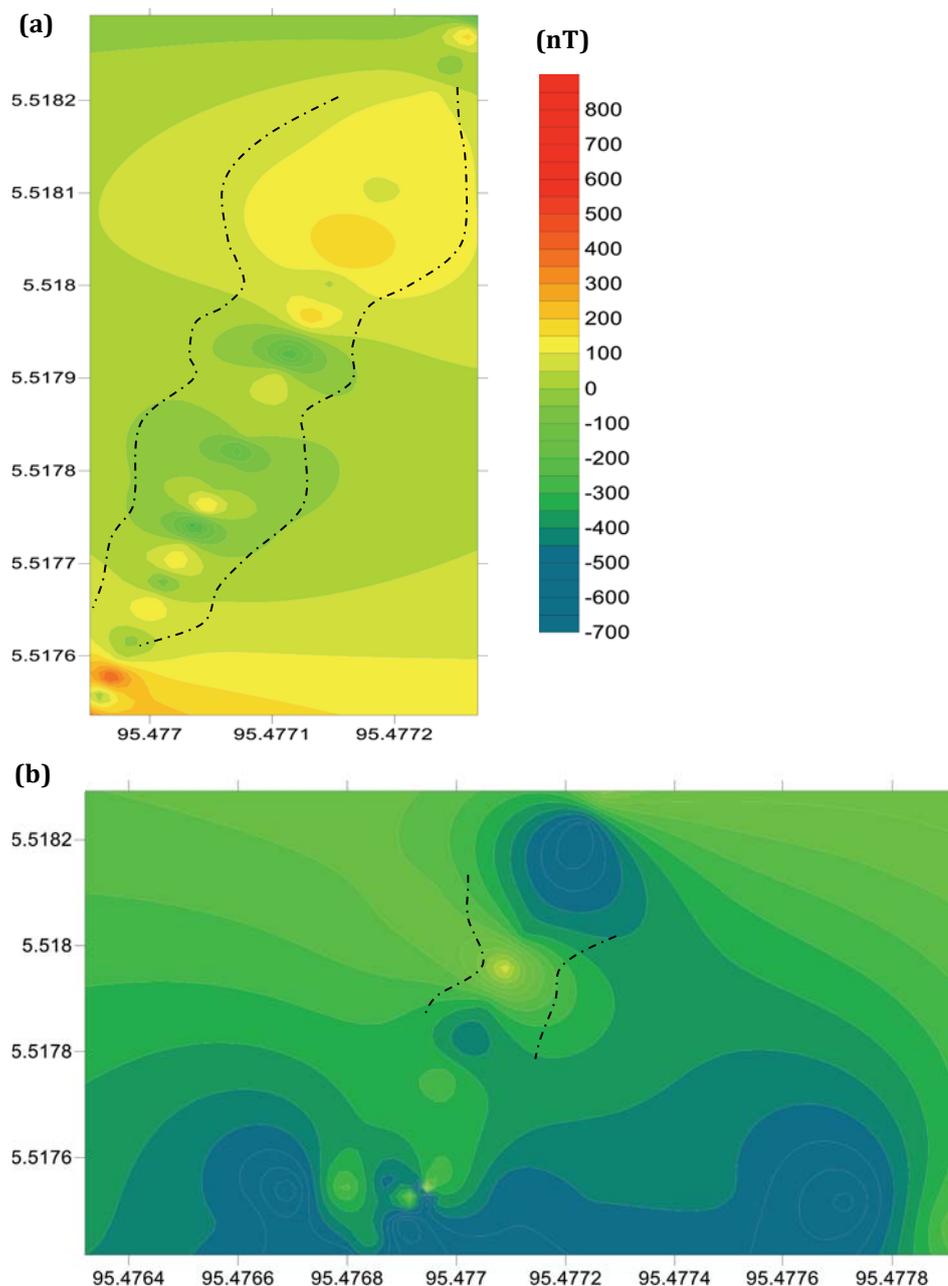


Figure 3. Magnetic Survey contour map in Blang Bintang (a). Survey are 1 (b) Survey area 2.

The weathered zone was interpreted if there was a high magnetic contrast. Generally, the total intensity magnetic anomaly map of Blang Bintang, Aceh Besar (Indonesia) shows higher magnetic anomalies

over eastern part (area 1) and low magnetic anomalies over western part (area 2) of the study area, which indicate the presence of weathered zone covering these parts. As can be seen from the images, high magnetic signatures were noted in most of the area in the north and some sections in the south. This weathered zone is directly related to the disaster-prone zones, and need to take the mitigation action, before the disaster.

Hence, the areas with lower magnetic values than the surroundings could be due to the presence of weathered zone beneath the surface (black dashed lines). Such values of magnetic intensity responses could be due to the characteristic of geological sediments such as clay, gravel and schist within the zone. Beside that, the important lateral variations and contrasts in magnetic properties of the shallow formations are brought singularly or by some combination of faulting, deposition and mineralization associated with volcanic rock. These volcanic rocks may produce high amplitude of magnetic variations in a very local extent. From the magnetic maps, several of the anomalies can be clearly correlated with geological map.

4. Conclusions

A simple pattern recognition technique can be used to locate weathered zones that have a varied magnetic response. The study has shown that the ground magnetic method can be used as an efficient method for delineating weathered zone in study area. There was a good relationship found among the geological characteristics and yield data in the study area. The maximum variation of magnetic intensity observed along area 1 might be an indication of intrusion of the overlying layer by the weathered basement. The low magnetic intensity of the weathered basement recorded along this profile (area 1 and 2) suggests that weathered basement is composed of consolidated earth materials. The magnetic responses of the weathered layer along the study area are characterized by clay, gravel and schist. The appearance of this zone is more dominant in area 1 than area 2. The variations in the magnetic intensity responses of the weathered basement suggest the heterogeneous nature of the layer. This is related to the location of landslides, so it is necessary to mitigate disaster.

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References

- [1] Parasnis, D.S., 1972, Principles of Applied Geophysics. Second Edition. Chapman and Hall Ltd. London. pp. 180-214.
- [2] Reynolds, R.L, Rosebaum, J.G., Hudson, M.R and Fisherman, N.S, 1990, Rock magnetism, the distribution of magnetic minerals in the Earth's crust and aeromagnetic anomalies in Hana, W.F., ed., Geologic Applications of Modern Aeromagnetic Surveys: U.S. Geological Survey Bulletin 1924 pp.24-45.
- [3] Lowrie, W., 2007, Fundamentals of Geophysics, second edition, Cambridge University Press, New York, pp. 281- 334.
- [4] Benson, R.C., 2006. Remote Sensing and Geophysical Methods for Evaluation of Subsurface Conditions. In: David M. Nielsen (editor), Practical Handbook of Ground Water Monitoring. Lewis Publishers, Inc. Chelsea, Michigan. pp.249-296.
- [5] Kearey P., Brooks M., Ian Hill, 2002, An Introduction to Geophysical Exploration, Third edition, Blackwell Science Ltd, London, pp. 155-183.
- [6] Mariita, N.O., 2013, Strengths And Weaknesses Of Gravity And Magnetics As Exploration Tools For Geothermal Energy, *Short Course VIII on Exploration for Geothermal Resources*,

organized by UNU-GTP, GDC and KenGen, at Lake Bogoria and Lake Naivasha, Kenya, Oct. 31 – Nov. 22, 2013.

- [7] Bennet, J. D., Bridge, D. Mc., Cameron, N. R., Djunuddin, A., Ghazali, S. A., Jeffery, D. H., Kartawa, W., Keats, W., Rock, N. M. S., Thomson, S. J. and Whandoyo, R. 1981, Peta Geologi Lembar Banda Aceh, Sumatra (1:250.000). Geologic Map of the Banda Aceh Quadrangle, Sumatra, Lembar (Quadrangle) 0421 (Banda Aceh), pp. 19, Bandung.
- [8] Gasparon, M. 2005, Quaternary volcanicity. (In: Barber, A. J. et al. (Eds.): Sumatra, Geology, Resources and Tectonic Evolution), pp. 120 – 130, London.
- [9] Ploethner D., and Siemon B., 2006, Hydrogeological reconnaissance survey in the province Nanggroe Aceh Darussalam, Northern Sumatra, Indonesia – Survey area Banda Aceh / Aceh Besar 2005, Helicopter Project Aceh (HELP ACEH). *BGR Report Vol. C-1*, Archives No. 0126196 C-1, Hanover.
- [10] Milsom, J. S., 2005, Seimology and neotectonics. (In: Barber, A. J. et al. (Eds.): Sumatra, Geology, Resources and Tectonic Evolution), pp. 7 - 15; London.
- [11] Nordiana, M.M., Syukri, M., Saad, R., Marwan, and Kamaruddin, N.A., 2014, The Identification of Fault Zones in Krueng Raya, Aceh Besar (Indonesia) Using Magnetic Method, *The Electronic Journal of Geotechnical Engineering*, Vol. 19., Bundle A. pp.1-9.
- [12] Syukri, M., Marwan, Safitri, R., and Saad, R., 2015, Delineation of Potentially Contaminated Zones by Electrical Resistivity Method in Aceh Besar, Indonesia, *The Electronic Journal of Geotechnical Engineering*, Vol. 20, Bundle 22, pp.12195 – 122012.
- [13] 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.
- [14] 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.
- [15] Begonha A. and Sequeira Braga M.A. 2002. Weathering of the Oporto granite: Geotechnical and physical properties. *Catena* **49**, pp. 57–76.
- [16] Dewandel B., Lachassagne P., Wyns R., Maréchal J.C. and Krishnamurthy N.S. 2006. A generalized 3-D geological and hydrogeological conceptual model of granite aquifers controlled by single or multiphase weathering. *Journal of Hydrology* **330**, pp. 260–284.
- [17] Hall, K. 1993: Enhanced bedrock weathering in association with late-lying snowpatches – evidence from Livingston Island, Antarctica. *Earth Surface Processes and Landforms*, vol. 18, pp. 121–129.
- [18] Hall, K. 1997: Rock temperatures and implications for cold region weathering. I: New data from Viking Valley, Alexander Island, Antarctica. *Permafrost and Periglacial Processes*, vol. 8, pp. 69–90.
- [19] Jones, J., 2002, Managing small teams, Penguin, Sydney.
- [20] Lan H.X., Hu R.L., Yue Z.Q., Lee C.F. and Wang S.J. 2003. Engineering and geological characteristics of granite weathering profiles in South China. *Journal of Asian Earth Science*, vol. 21, pp. 353–364
- [21] Goudie, A.S., Migon, P., Allison, R.J. and Rosser, N. 2002: Sandstone geomorphology of the Al-Quwayra area of south Jordan. *Zeitschrift für Geomorphologie* **46**.
- [22] Olona, J., Pulgar, J.A., Viejo, G.F., Fernández, C.L., and Cortina. J.M.G., 2010, Weathering variations in a granitic massif and related geotechnical properties through seismic and electrical resistivity methods, *Near Surface Geophysics*, vol.8, pp.585-599.
- [23] Sharma, V.P., 1997, Environmental and Engineering Geophysics, published by Cambridge University Press, United Kingdom. pp. 40-45.