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ORIGINAL RESEARCH

Application of magnetic method for mapping buried structures around archaeological site of Masjid Tuha Indrapuri

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Abstract. Magnetic gradiometer survey has been conducted on the yard of the archaeological site of Masjid Tuha Indrapuri, Aceh Besar Regency, Aceh Province. The site is one of the oldest mosques erected during the Aceh Sultanate period. Magnetic method was applied for mapping archaeological structures buried beneath the surface. Total magnetic field data were measured using Proton Precession Magnetometer with grid spacing of 2 meters between stations covering the entire area of the site. Diurnal and international geomagnetic reference field data were corrected to the measured data in order to calculate total magnetic field anomalies that were influenced by the buried magnetic objects. The total magnetic field anomalies distribution shows two elongated structures with U-shaped patterns surrounding the mosque. The patterns are also revealed in reduction to the pole and derivative vertical filters of the total field anomaly data. The anomaly patterns are considered a response from the rest of the buried fences that were built around the mosque in the past.

Keywords: magnetic method, Aceh cultural heritage, geophysical archaeology, near surface geophysics.

INTRODUCTION

Aceh is an area that has inherited many cultural heritage sites from the past. Some of them are still visible on the surface, but many of them have been damaged or buried beneath the surface. These heritage sites need to be saved and preserved for education and historical monuments. The ancient mosque of Masjid Tuha Indrapuri (Figure 1) located in Indrapuri District, Aceh Besar District is one of the famous heritages. The mosque was once used as the coronation of last Sultan of Aceh, Tuanku Mohammad Daudsyah, in 1878. The building stands on an area of 33,875 M² and is located at an altitude of 22 meters above sea level from the tributary of the Krueng Aceh river [1], i.e. about 27 km from Banda Aceh to the east (Figure 2). Considering Aceh's cultural and historical values, Masjid Tuha Indrapuri still lacks information that can be used to preserve the site.

Preservation of this historical site can be done by archeological excavation; however, the method is costly and time consuming. Near surface geophysical methods are used usually for acquiring preliminary information on archaeological studies. Geophysical methods are very environmentally friendly and do not damage the historical sites being studied. Geophysical methods can be used to investigate various physical properties of subsurface rocks and rocks, both naturally formed and human-made products.

Geophysical exploration in archeological studies has been carried out and developed in the last few decades, starting in the 1950s, namely the measurement of resistivity by injecting electric currents and also measuring the proton magnetometer by utilizing potential field theory [2]. Magnetic method is one of the geophysical methods that are often used for investigation of archaeological objects. The method is favored in geophysical archaeological surveys and is often used by several geophysicists in various regions [3-14].

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Figure 1. Masjid Tuha Indrapuri viewed from the front.

The magnetic method has been able to identify structures that are buried beneath the surface such as walls made with stone or footprints made of wood [15]. Based on success stories, a magnetic survey has been conducted at Masjid Tuha Indrapuri archaeological site to map artifacts and structures buried beneath the surface. This study was focused on the back yard of the mosque to acquire additional information that can be used for preserving the existence of the site and reference for further research.

Figure 2. Location sketch of Masjid Tuha Indrapuri (Google Earth™)

METHODOLOGY

The magnetic method, sometimes referred to as the geomagnetic method, is a technique most often used to investigate archaeological objects or sites of cultural heritage buried under the surface. This method can be operated fast and provide a high-resolution image in mapping archaeological sites covering a large area. The method is also considered cost effective. Geomagnetic method theoretically is based on magnetic properties of rocks which depend on the susceptibility and magnetic remanence.

This research applies the magnetic gradiometer measurement which is the development of the magnetic method in the data acquisition process. This method has also been used by several geophysicists for archaeological mapping [16-18]. This method is considered to have a relatively high resolution and is able to detect anomalies up to 0.5 m in diameter depending on the survey resolution [19]. In data acquisition, i.e. total magnetic field data, two magnetometers mounted vertically were used, so that it can eliminate the effects of the earth's magnetic field and only map the effects caused by anomalies below the surface.

Measurement of the total magnetic field data in the field was done with grid spacing of 2 meters between stations on the back yard of the mosque (Figure 3). The data measurement was done to cover the entire area, so that a detailed information of the near surface can be obtained. In addition, this study also uses several data filters on the distribution of magnetic anomalies to get clearer results and make it easier to interpret the data.

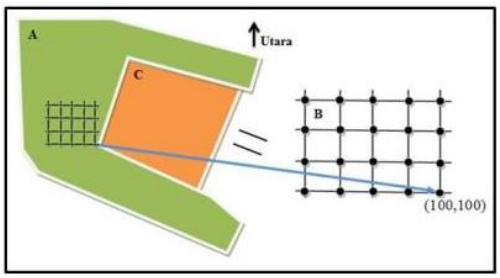

Figure 3. Area of data measurement shown in green color (A), Grid spacing 2 meter (B), and the old mosque shown in orange color (C).

RESULTS AND DISCUSSION

The total magnetic field data measured on the area are not only caused by the archaeological objects as target in this survey. Magnetic fields caused by external and main geomagnetic fields are mixed in the measured data. Several data corrections have been applied to the data. Total magnetic field anomalies that come from the archaeological and near surface objects are found after the correction. Diurnal corrections have been done to eliminate the measured data by the effects of the external magnetic field. The international geomagnetic field reference (IGRF) corrections were performed for eliminating the data from effect of the Earth's main magnetic field.

The total magnetic anomalies distribution map (Figure 4) shows that the area of Masjid Tuha Indrapuri has the lowest total magnetic field anomaly value of -273 nT and the highest value is around 451 nT. The minimum values of the total magnetic anomaly map show consistent elongated patterns of U-shape. This pattern surrounds the south, west, and north of the main the building of Masjid Tuha Indrapuri. This total magnetic field anomalies are still mixed

between residual anomalies and regional anomalies, so filtering is needed on the magnetic anomaly data to reduce ambiguity in the distribution of magnetic anomalies in the site area.

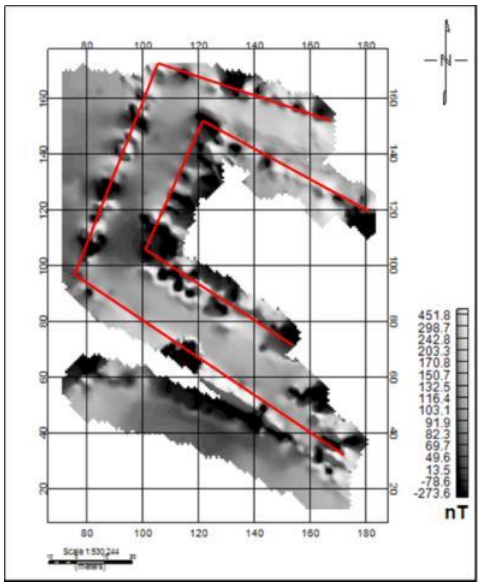

Figure 2. Total magnetic field anomalies map. The red lines show anomalies patterns that may reflect subsurface structures.

In order to enhance the data, the total magnetic field anomalies were transformed using reduced to the pole (RTP) method. The RTP transformation can eliminate the effect of inclination on total magnetic field data measured at law latitude geomagnetic, which are dipole, to the geomagnetic pole as monopole anomalies. The RTP map is shown in Figure 5. The total magnetic field anomaly of reduction to the pole transformation ranges from -2500 nT to 1900 nT.

In addition to reduction to the pole transformation, vertical derivative calculation was also applied to the total magnetic field anomalies. Maximum and minimum values of the vertical derivative of total magnetic field anomaly are 198 nT and -167 nT, respectively. The minimum values of vertical derivative anomalies enhance the elongated U-shaped patterns around the mosque clearly (Figure 6). The vertical derivative data provides shortwave information of the data so that it reflects the existence of shallow magnetic bodies.

Based on the comparison of the three magnetic anomaly maps, i.e. total magnetic field, reduction to the pole and derivative vertical anomalies, all of them show a similarity in the pattern of anomalies. The elongated U-shaped patterns are found around the main building. This magnetic anomaly pattern is more clearly displayed by the total magnetic anomaly and the derivative vertical anomaly maps, but less clearly seen in the RTP map.

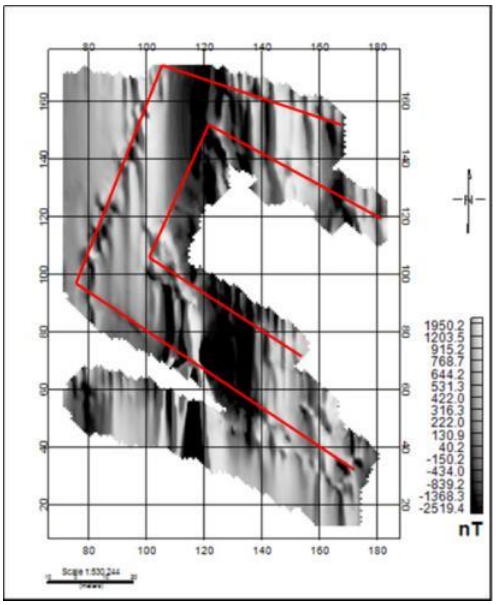

Figure 3. Reduced to the pole of the total magnetic field anomalies distribution.

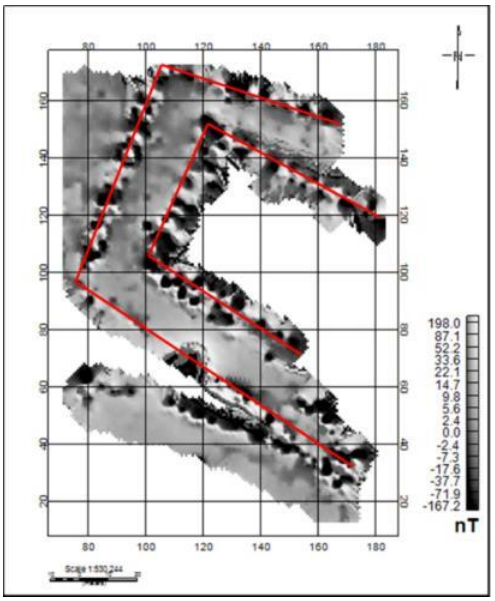

Figure 4. Derivative vertical data calculated from the total magnetic field anomalies.

Although both maps reveal U-shaped patterns of low magnetic field values. In the reduction to the pole map, the U-shapes patterns are too smooth, while in the vertical derivative map the patterns are clearly seen. The patterns are interpreted as a response to buried fences that surround the mosque in the past. Some outcrops can still be seen on the surface. They were noticed during the data measurement performed. Based on the maps, it can be interpreted that the old mosque of Masjid Tuha

Indrapuri was surrounded by two fence walls. One of the fences was just beside the building or probably caused by the building wall itself and other fences are situated around the mosque. The elongated structures are hardly seen in the RTP map since the RTP method transformed the dipole effects as monopole objects. The RTP method works well when the target magnetic objects are not elongated.

CONCLUSION

Magnetic method has been successfully applied for mapping buried objects around the archaeological site of Masjid Tuha Indrapuri. In order to emphasize the appearance of shallow objects recorded from measurements of total magnetic field data in the area of low magnetic latitude such as in Masjid Tuha Indrapuri, the reduction to the pole and vertical derivatives calculation are very useful to be used. Both maps show near surface man-made objects around the main building that could be interpreted as buried fences from the past. These buried structures need to be excavated and repaired for further archaeological studies and preservation.

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REFERENCES

[1] Balai Pelestarian Cagar Budaya Aceh Wilayah Kerja Provinsi Aceh dan Sumatera Utara 2017 *Berkas Pendaftaran Bangunan Cagar Budaya Benteng Dan Masjid Indrapuri Sebagai Cagar Budaya Nasional* (Banda Aceh: Balai Pelestarian Cagar Budaya Aceh Wilayah Kerja Provinsi Aceh dan Sumatera Utara)

[2] Aitken, M.; Webster, G. and Rees, A. 1958. Magnetic prospecting. *Antiquity.* **32**, 270–271.

[3] Behzad, S. and Hamid, A. 2017. Archaeological investigations at Tepe Hissar-Damghan using Gravity and Magnetics methods, *J. Res. Archaeometry* **2**(2), 19-34.

[4] Gaffney, C. and Gater, J. 2003 *Revealing the buried past: geophysics for archaeologists* (Strout: Tempus Publishing Ltd.)

[5] Bruce, W.B. and Tatiana, N.S. 2013. Magnetic exploration of archaeological sites. in good practice in archaeological diagnostics: non-invasive survey of complex archeological site, *Nat. Sci. in Archeol.* **3** 133-152.

[6] Roger, S.; Ekhine, G. and Robert, T. 2012. *Archaeological Geophysics - From Basics to New Perspectives. in Archaeology, New Approaches in Theory and Techniques*, Dr. Imma Ollich-Caster (Ed.), (Budapest: InTech)

[7] Batayneh, A. and Awni T. 2010. *Archaeogeophysics-archaeological prospection - A mini review* (Saudi Arabia: Department of Geology and Geophysics, King Saud University)

[8] Campana, S.; Piro, S. 2009. *Seeing the Unseen Geophysics and Landscape Archaeology* (London: Taylor and Francis Group)

[9] Jörg, W.E.F. 2016. Magnetometry for Archaeology. In *Submerged Continental Shelf Prehistory* (Netherland: Springer)

[10] Schmidt, A. 2009. Electrical and Magnetic Methods in Archaeological Prospection. In S. Campana; S. Piro (eds) Seeing the Unseen. *Geophysics and Landscape Archaeology* (London: Taylor & Francis Group)

[11] Schmidt, A. 2007. Archaeology, magnetic methods. In Gubbins, D.; Herrero-Bervera, E. (eds) Encyclopedia of Geomagnetism and Paleomagnetism: *Encyclopedia of Earth Sciences Series Heidelberg* (New York: Springer)

[12] Batayneh, A.; Khataibeh, J.; Alrshdan, H.; U. Tobasi, U.; Al-Jahed, N. 2007. The use of microgravity, magnetometry and resistivity surveys for the characterization and preservation of an archaeological site at Umm er-Rasas, Jordan. *Archaeol. Prospect.* **1** 60 – 70.

[13] Eppelbaum, L.V. 2010. Archaeological geophysics in Israel: past, present and future. *Adv. in Geosci.* **24** 45–68.

[14] Fassbinder, J. 2009. *Geophysical Prospection: a Powerful Non-destructive Research Method for the Detection, Mapping and Preservation of Monuments and Sites* (Munich: Bavarian State Department of Monuments and Sites).

[15] Armstrong, K.; Darvill, T. and Cheetham, P. 2009. Archaeological geophysical

prospection in peatland environments: Case studies and suggestions for future practice. *J. Archeol. Sci.* **33** 251-253.

[16] Stamnes, A. A. 2016. *The Application of Geophysical Methods in Norwegian Archaeology: A study of the status, role and potential of geophysical methods in Norwegian archaeological research and cultural heritage management* (Norwegia: Department of Archaeology and Cultural History, Norwegian University of Science and Technology).

[17] Oswin, J. 2009. *A Field Guide to Geophysics in Archaeology* (Berlin: Springer).

[18] Aspinall, A.; Gaffney, C. and Schmidt, A. 2008. *Magnetometry for Archeology* (, Lanham, Maryland: Altamira Press).

[19] Gaffney, C.; Gater, J. 2003. *Revealing the Buried Past: Geophysics for Archaeologists* (Strout: Tempus Publishing Ltd.).