Detecting the Artifacts using Gradiometer Magnetics at Pande Village, Banda Aceh-Indonesia

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Abstract. Pande village is a historical village in Banda Aceh. The village is flanked by two other villages, which are Jawa and Peulanggahan village. It was ever became the center of civilization kingdom of Aceh Darussalam and was also as a magnificent port and furthermore also known as a craftsman of precious stones and metal objects. In this village, there were discovered archaeological objects such as gold coins, swords and old wells. Archaeology is a science which studies human behavior in the past. One method used to search for archaeological objects is gradiometer magnetic, because this methods seek to the total variation of the magnetic field gradient. The research was carried out in related to finding of heritage of ancient time using gradiometer magnetic GSM-19T. Recording data was done at coordinates N 05°34,285’ dan E 95°18,822’ in grid pattern having 289 points and 1 meter spacing. Data processing done using Surfer software for making a contour map and 3-D model. Based on data processing can be interpreted from contour map that describes an anomaly that can clearly be seen between point J6 and K6 compared to surrounding values regarded as the metal objects or features of Aceh Kingdom heritage which is buried in around 3 m depth. In addition to the result above, this method also proves that it can be helpful used for seeking the archeological features wherever in ranges of shallow subsurface investigations.

Keywords: archeology, gradiometer, magnetometer, gradient, anomaly, Pande village

INTRODUCTION

Indonesia is one of the countries which is rich in heritage of the past including in Aceh whose civilization such as the heritage of Aceh kingdom government. The one of the Aceh’s civilization existed in Pande village which is a historical city in Banda Aceh. This village is located in between two other villages that is Jawa and Peulanggahan village. In the past, Pande village is one of the prominent ports in Aceh at which Darussalam Aceh kingdom was built by Ali Mughayat Syah. Geographically, this village was bordered to the sea because of that it was became the center of Aceh kingdom before moving to Darud Dunia Palace. The Pande village’s name can be found in Pocut Muhammad’s tale which composed in the beginning 18th century by Karel F. H van Langen titled “Susunan Pemerintahan Aceh semasa Kesultananan”, published in 1986. Pande village has known as the site of metal and precious stones craftsman that is why it is named as Pande village. (http://gunongan.blogspot.com/2013/01/Gampong-pande-laboratorium-sejarah-yang.html). In this village was ever found artifacts such as gold coin, old well and sword as the heritages of Aceh kingdom government. The study area is portrayed in figure 1.

Based on [4], archaeology is sciences which study about human behavior in the past seeing through the track of sample left by them. In its advancing, archaeology is a science studying human life either in the past or modern stressing on all of relation the cultural objects with behavioral human at the whole time and place. Generally the purpose of archeology efforts is to reveal human behavior in the past. One of the methods used to map artifacts is using gradiometer magentics. Gradiometer is the device for measuring vertical gradient of earth magnetics field and also can detect local variation magnitude of its. This variation can be caused by several natural factors that changes and influences earth magnetics filed. In term of searching artifacts, the variation investigated is the total of magnetics field gradient. Being mapping the artifacts intended can be found new artifacts in Pande village area which is used as for backing preservation of remaining heritage of the past. The gradiometer, an instrument that is an adaptation of the conventional magnetometer, give the gradient of the magnetic field. The gradient
is especially useful for detecting objects buried at shallow depth (the gradient is the quantity measured by magnetic locators used in land surveying). In addition to the application discussed in this paper, magnetic surveys have broad general application in passive surface searches for buried cultural objects, or searches for areas of prior human disturbance [7]. The history of applying geomagnetism in archeology has begun in Europe during the fifties of the last century². Later on, it started in Egypt by [5] who had measured land magnetic survey using proton magnetometer at Kom Oshim and Kiman Fares areas (Fayoum). During the nineties of the last century, the application of geophysics in Egypt began to use advanced magnetic instruments with real archeological discoveries³. Most of the Egyptian archeological features are made from mud bricks which contain some magnetic minerals (e.g. magnetite, hematite of high magnetic susceptibility), which are the reason for their high magnetization. So, they can be detected by sensitive magnetic instruments.

FIGURE 1. Map of the study area (http://bappeda.bandaacehkota.go.id)

The problem of traditional and random archeological excavations are time consuming and need effort and money. So that, the best way to explore the archeological remains is using passive geophysical tools (e.g. magnetic, electric and electro-magnetic methods) without destroying or digging in the archeological sites. A gradiometer survey is used to detect and map small changes in the earth's magnetic field caused by concentrations of ferrous-based minerals within sediment units³. This variation in magnetic materials includes two principal types of magnetism, termed magnetic susceptibility and thermoremanance. Contrary to popular and some professional opinion, a gradiometer survey does not map archaeological remains. Gradiometer surveying is used to detect changes in sediment architectures via changes in magnetic fields, which can be related to human activities and interpreted as archeological features. As such, gradiometer survey has the ability to detect a range of anomalies that are not related to human activity but produce magnetic fields.

Archaeological gradiometer surveying is based on the principle that different types of sediment architecture have different magnetic properties. This occurs within the soil profile, where the A, B and C horizons have different magnetic properties; hence excavation, backfilling or inversion of these profiles creates different magnetic signals. Likewise, different magnetic fields also occur between different sediment units, whether they are part of a soil profile or not. Lastly, different geological strata have different magnetic fields. These three types of magnetic variations, vertically in a soil profile or both vertically and laterally in sediment sequences and geological magnetic fields, form the basis of all gradiometer surveying. Human activity often causes distinct magnetic anomalies through interaction with the magnetic properties of soils, sediments and geologies. The research objective is to detect the area estimated existed artifacts using gradiometer magnetics method by utilizing the variation of vertical earth magnetic field.

METHODOLOGY

In this measurement the device used is the gradiometer magnetic GSM-19T. Taking data is done at Pande village, Kutaraja sub-district Banda Aceh city at March, 19th -20th, 2014 and was measured at coordinates N 05°34,285’dan
In the acquisition data at the field, path of the measurement is in grid pattern which has 289 points and 1 meter spacing at each other intended to get more detail data. Technically, recording data was done by the way of walking from one point to another starting from the South to the North and at each point, it is recorded 3 times repeating and numbers of lines are 15 lines as shown in figure 1. Data processing was done using Surfer software. It is used for making a contour map and 3-D model based on grid pattern that is the vertical and horizontal lines becoming square shape. The gradiometer magnetics data are no need to be corrected because they are not influenced by outer magnetics field. Before processed, at first, they are averaged because of three time recordings.

In the Surfer software is also needed coordinates because of obtaining the detail information. In term of that purpose the coordinates used is local coordinates that are X and Y. After averaged value obtained, the data is plotted using the Surfer. Then, analysis and interpretation data was done qualitatively. The summarizing process of research methodology stages is drawn in figure 3 below:
Gradiometer magnetic is suitable for detecting artifacts because they exist at shallow subsurface of the earth. The data obtained is the total magnetics field from the total magnetics field of below censor subtracted with the total magnetics field of above censor and divided by the distance between two sensors. The total magnetics field portrayed as a contour map can be seen in figure 4 which indicates a presence some of metal features because of existing voids causing either arise or reduction the total of magnetic field which is called as an anomaly.

The presence of a nonmagnetic void in the subsurface, such as fiber glass storage tanks, metal object and others, if the surrounding soil materials are magnetic. The presence of a lateral variation in magnetic properties due to an object or void in the subsurface gives rise to a lateral variation in the magnetic field at the surface of the earth, above the object. The variations in the magnetic field arise either because the object has a large magnetic field of its own that adds to the background magnetic field, or alternatively, in the case of a void at depth, because the absence of alluvial material in the void gives rise to a local reduction in the magnetic field. From contour map below (Fig.4), it was revealed an anomaly that is marked by red box that can clearly be seen between point J6 and K6 compared to surrounding values, so then that is quite regarded as the metal objects which are the artifacts because the high analytical signal anomaly could represent occurrence of shallow buried magnetic sources within subsurface and confirms the probable occurrences of archeological remains causing magnetic positive anomalies, while the normal anomaly in Pande village area is around 0-100 nT/m. Furthermore, this method also proves that it can be effectively used for searching the artifacts in everywhere in ranges of shallow subsurface investigations.

The application of vertical magnetic gradient at the Pande village has successfully achieved the aim of the present study. The delineated archeological features are mostly belonging to the Aceh Kingdom. The measurement of the vertical magnetic gradient of the geomagnetic field gives more accurate results than the measurement of the total magnetic field, in particular, in the near-surface applications. The fluxgate gradiometer is highly recommended for shallow investigations (e.g. archeology, engineering, etc.) than the normal magnetometers. The estimated depth of the buried features is expected to be very shallow (3 m). Successful delineation of archeological features at the area of Pande village lead to more information about the characteristic behavior of the Aceh Kingdom’s glorious era.

**FIGURE 4.** The contour map showing the total of magnetics field variation
To prove the result pointed out above, it would be better to excavate the underlain objects within subsurface where they were exactly mentioned to see in direct way. Furthermore, soil and rocks where the objects or artifacts were found should take out as the samples to analysis either chemically or physically in laboratory. There are any possibilities of them which have been completely became the soft sedimentary rock because of weathering process so that they cannot be identified directly by naked eyes. From the analysis, they would be revealing what kinds of soil and rocks which may also be the object of heritage, such as cooking pot made of clays as Aceh Kingdom’s civilization. These results are very helpful in term of tracking back the Aceh Kingdom’s history that has slowly disappeared in nowadays. In addition to this, the usefulness of this method is doubtless to unveil the buried objects especially as metal objects. That were so many evidences proven by geophysicists in connection with advantages of geophysical method which is not destructively. In many countries whose historical sites, this method is quite popular proving the track of ancient life.

CONCLUSION

According to results and discussion, it could be summarized that Gradiometer magnetics method is simply helpful in term of unveiling the heritages such as artifacts, the buried lines including electrical power lines, telecommunication cables, etc. because this method could map the anomaly with good accuracy. In other wise means that it records the variation of total magnetics field gradient without influenced by the time variation. The guessed objects, which are artifacts, are drawn between J6 and K6 point

Gradiometers offer excellent potential for location of buried cultural features of interest for site investigations that focus on objects’ heritage. The methods could be useful in other types of investigations as well. These magnetic surveys can be applied even in areas where known cultural features arc abundant.

Measurements of the magnetic field strength and its vertical gradient arc easily obtained with commercially available instrumentation. Precise horizontal location of measurements is critical if interpretable results arc desired.. Since both can be acquired at the same time, with no additional effort, the added constraints on interpretation warrant the use of both for many site investigations.

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REFERENCES


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