

Application of gravity method in cultural heritage Cot Sidi Abdullah Site, Samudera Pasai, North Aceh

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Abstract. The gravity method was applied to the cultural heritage site of Cot Sidi Abdullah in Kuta Krueung Village, Samudera Pasai District, North Aceh Regency for mapping and reconstruction structure of the cultural heritage site and distribution of artifact objects buried in the subsurface. Data measurement was carried out in a grid with 2 meters spacing between the points to cover all area of the cultural heritage site. The model of gravity anomaly distribution from the vertical derivative results shows a square pattern of anomaly gravity surrounding the measurement areas. This anomaly pattern is thought as a response from the remaining walls of the site structure which are buried in the subsurface with anomalous values between 0.02 mGal/m - 0.08 mGal/m. The estimation of the walls of the archaeological site from the anomalous response to this gravity value is proved by the excavation results in the southern part of the study area. While the minimum value of the vertical derivative filter (-0.06 mGal/m to - 0.01 mGal/m) is the response from the area around the archaeological site. The reconstruction results of the site based on the estimation of the walls with a length of ± 45 meters and a width of ± 40 meters.

Keywords: Geophysics Method, Archeology, Cot Sidi Abdullah, Gravity Method

INTRODUCTION

The geophysical method is one of the method that is often used for environmental studies, disaster mitigation, geotechnical engineering, and exploration of natural resources such as minerals and groundwater [1]. In addition, the geophysical method has also an important role in the archeological fields because it can map the sites and provide an overview of archeological objects that are under the surface without damaging the object [2]. Geophysical methods can measure the various physical properties of subsurface rocks, both natural and man-made.

Geophysical survey method is an initial survey that aims to mapping the subsurface regarding

geological structures, stratigraphy, rock lithology and reservoirs and geophysical method is the first step to find out the rock layers in the subsurface [3]. The capability to mapping archeology presents its own challenge, namely the geophysical methods ability to detect relatively small objects. So that in this case not only the sensitivity of the geophysical equipment is needed but also measurements with close distances to produce a good and high resolution [4]. The uses of integrated geophysical methods will provide better results and accuracy [5]. The gravity method is one of the geophysical methods that can be used for archeological studies with good sensitivity to large objects [6]. The gravity method is usually used in underground, tunnels, castles, and caves as an identifying subsurface geological structure. The widespread use of the gravity method can solve geological and environmental problems such as depicting ancient

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underground galleries on Moscow's Red Square [7] and used to predicted the weight of the pyramid of Cheops in Egypt [8].

This method has experienced many improvements both in terms of data acquisition, instrumentation, and data interpretation and data processing [9]. Although the uses of the gravity method is rare in archeological surveys, mapping the site building the gravity method can be seen as good. The uses of geophysical methods for archeological studies is still less such as the research for old temples in Java. This geophysical study needs to be developed especially to mapping the sites of high-value cultural heritage in Aceh for the preservation and rescue of the sites, such as historical sites in the Kingdom of Samudera Pasai.

Samudera Pasai Kingdom is the first Islamic Kingdom in Southeast Asia which reached its heyday around the 14th century. The most of the buildings in the Samudera Pasai Kingdom have been damaged and buried by sediment in subsurface that is caused by floods, tsunamis and tidal waves [10]. The one of the heritage building of the Samudera Pasai Kingdom is the Cot Sidi Abdullah site. Nowday, the site is not visible, and only the remaining mounds of the grass. This site needs to be done with the preservation and rescue efforts without the excavation that can damage the site.

Previously, an initial mapping of the Cot Sidi Abdullah site had been carried out using the gravity method in an effort to find the structure of the site's buildings and artifact objects buried in the subsurface [11]. However, the research was done in half areas that are thought the site buildings. In this study, researchers continued the previous study to mapping the remains of the structure of the Cot Sidi Abdullah site.

METHODOLOGY

The gravity method measures the difference in the acceleration of gravity so as to produce density or mass density [12]. The gravity method is a geophysics method used to measure the difference in acceleration of gravity to produce density or mass density. The instrument used to measure the acceleration of gravity is a gravimeter with an accuracy of 0.001 mGal [13]. The measurement stage carried out in this study is to determine the base of the measurement station as a data reference point, leveling the gravimeter which aims to balance the position of the gravity tool so that the spring position is not tilted which disturbs the pulling force of objects under the surface. Data measurement is done by looping which starts from the base station in the morning and ending at the same base station in the afternoon. GPS is

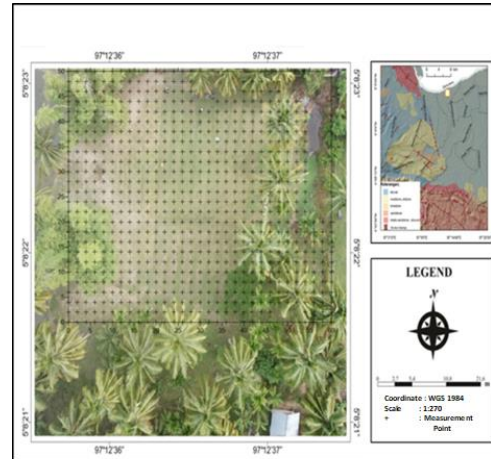


Figure 1. Area and spacing of gravity measurements in Cot Sidi Abdullah Site

used to measure the distance between sample point, the height data, latitude and longitude coordinates.

The measurement of gravity data in the field is done in a grid with 2 meters spacing between measurement points as shown in Figure 1. This is done to cover all areas suspected of remnants of the Cot Sidi Abdullah site building structure, to obtain more detailed results' regarding the site structure has been buried in the subsurface. There are several corrections in gravity value which has the tidal correction, drift correction, latitudes correction, air correction, and Bougeur correction [14].

Correction need to implemented to eradicate some factors which influence the gravity value data reading, so that only the gravity values is obtained which is the response of the objects under the surface. In addition, this study also utilizes several filters on the distribution of gravity anomalies to provide clearer results and make it easier to interpret the data. Figure 1 below is pointing the area and the spacing in Cot Sidi Abdullah site.

RESULTS AND DISCUSSION

The measurement of gravity data obtained at the Cot Sidi Abdullah site does not reflect the actual conditions of object under the surface. The data is still influenced by various effects of Earth's gravity such as the influence of geographical latitude, and the influence of mass density. In addition, the measured value of gravitational acceleration is also influenced by the activity of space objects and the exhaustion of the gravitimeter equipment itself. Therefore, the measurement data of gravity at the site of cultural heritage needs to be done some correction of the data in order to obtain anomalous value of gravitational acceleration

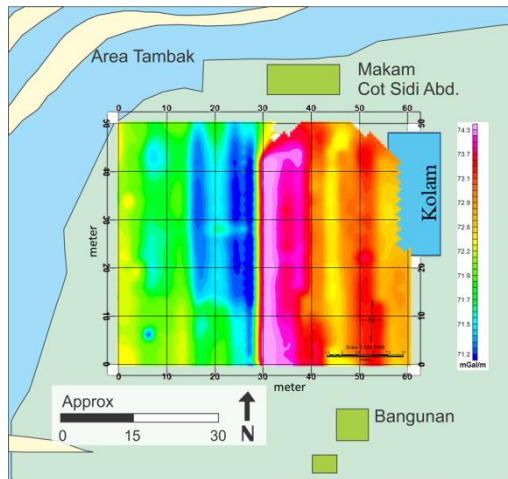


Figure 2. Bouguer Anomalies. The dotted line predicted as walls site.

of the target which is called the Bouguer anomaly as Figure 2.

Based on the Bouguer anomaly values at the Cot Sidi Abdullah site, the variations in gravity values were between 71,259 mGal to 74,289 mGal. This anomaly value is divided into 2 zones, namely the low zone and the high zone. The low zone is in the western of the site with anomaly values ranging from 71,259 mGal to 72,152 mGal. The low anomaly value is caused by data measurements close to the fish and river area, so that the soil Based on the Bouguer anomaly values at the Cot Sidi Abdullah site, the variations in gravity values were between 71,259 mGal to 74,289 mGal. This anomaly value is divided into 2 zones, namely the low zone and the high zone. The low zone is in the western of the site with anomaly values ranging from 71,259 mGal to 72,152 mGal. The low anomaly value is caused by data measurements close to the fish and river area, so that the soil experiences more water expectation and the soil density decreases. While the high anomaly value zone is located in the East of the site area with an anomaly range between 72,191 mGal to 74,289 mGal.

The distribution of Bouguer's anomaly has not clearly identified the structure of the wall of the building site under the surface, so filtering of Bouguer's anomaly data is needed to increase the contrast response of the site walls and artifact objects under the surface. The one of the filters used in this study is the vertical derivative technique. This technique is used to detect the edges of anomalous structures that are near vertical surfaces [15]. Figure 3 below is pointing the result of vertical derivative filter.

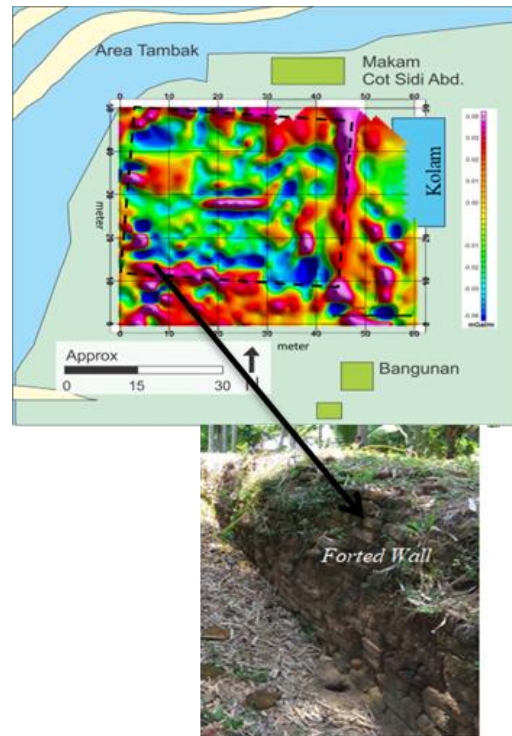


Figure 3. Vertical Derivative of Gravity Anomalies in Cot Sidi Abdullah site. The dotted lines predicted as walls site.

Based on the results of the vertical derivative maps distribution of Bouguer anomaly, it was found that the highest value identified the walls blocks of the Cot Sidi Abdullah site building structure that had been buried under the surface. This is evidenced by the findings of the excavation in the South of the study area, and measuring the value of the gravity right above the wall of the site. From the map the distribution of vertical derivative values as a whole is found that the anomaly pattern with the highest value forms a square in the measurement area. This pattern is interpreted as the walls of the Cot Sidi Abdullah site that are buried under the surface. While the anomaly with the lowest value is interpreted as the condition area around the site. This difference in anomaly value is also caused by the material making up the site wall made of high-density man-made bricks, so that the density is higher than the surrounding area.

Based on the result of Bouguer anomaly through vertical derivative filter, the length of the wall of 45 meters and the width of 40 meters. The result was the main point of information in reconstructing the archeological Cot Sidi Abdullah site. Figure 4 below shows the finished reconstructed building of Cot Sidi Abdullah Site.

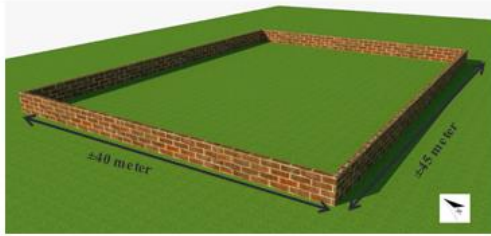


Figure 4. Reconstruction of the Cot Sidi Abdullah site.

Figure 5 presented the reconstructed building with the overlay of the examination area of Cot Sidi Abdullah

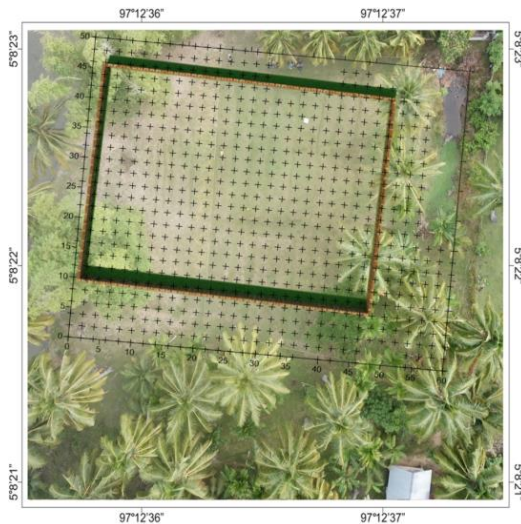


Figure 5. the illustration of Cot Sidi Abdullah site location.

CONCLUSION

The conclusion of this research is the structure of Cot Sidi Abdullah site which the heritage site of Samudera Pasai Kingdom could be mapped properly based on Bouguer anomaly using vertical derivative filters. The anomaly is obtained in a square which is a response from the walls of the archaeological site of Cot Sidi Abdullah, which has been buried in subsurface with anomalous values between 0.02 mGal/m - 0.08 mGal / m. The estimation of the walls of the archaeological site from the anomalous response to this gravity value is proved by the excavation results in the southern part of the study area. While the minimum value of the vertical derivative filter (-0.06 mGal/m to - 0.01 mGal/m) is the response from the area around the archaeological site. The reconstruction results of the site based on the estimation of the walls with a length of ± 45 meters and a width of ± 40 meters.

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