Analysis of The Bahal Temple III Site Using Combination Method of Geophysics

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Abstract. The Bahal III temple is an ancient relics temple of the Hindu Kingdom. The research aims to know the underlayer structure of the Bahal III surface and to determine the minerals contents of the boulder sample in the Bahal III temple in the Portibi region, North Padang Lawas. The research methods are Geoelectric and geomagnetic, and XRD methods. The geoelectric method that used in this research was the Wenner-Schlumberger method in two lines. Line length is 155m with 32 electrodes and 5m distance each. The geomagnetic method was done by using 60 grids. Geoelectric data processing used Res2Dinv software while geomagnetic data processing used Mag2DC software. Data processing of layer contouring used surfer11 software. Data processing of the XRD test result used Match3 software. The findings showed that the andesite rock layer was found using the geoelectric method with resistivity value 950 - 1500 Ωm suspected as the rock of temple forming in-depth 3 - 12m. Geomagnetic test results showed the susceptibility value 0.034(cgs unit) which is andesite rock. XRD test result for minerals contents of the temple boulder sample was dominated by mineral Silicon dioxide (SiO2) 88.8%, Ferric oxide (Fe2O3) 8.9 %, Magnesium oxide (MgO) 1.7% and Titanium dioxide (TiO2) 0.7 %.

Key words: Resistivity, Susceptibility, XRD, Bahal III Temple

1. Introduction

Indonesia is a famous country that has a high value ancient royal heritage. The biggest kingdom in Indonesia is Majapahit kingdom with one of the ancient relics of Majapahit kingdom are temples. Most of temples in Sumatera have been known in North Sumatera Province, especially in Mandailing Natal and South Tapanuli districts [1].

The Portibi Temple is located in the north Padang Lawas area. The most famous temple in Portibi area is Bahal Temple which consist of three temples, there are Bahal I, Bahal II, and Bahal III which located in Bahal village. Bahal Temple III is located in the area of Bahal Temple III, Bahal Village, Portibi sub-distric, North Padang Lawas district, North Sumatera Province which located in UTM coordinates (581713.3 m E, 155331.2 m N). The land area of Bahal III about 4.322 m2. The boundaries of the temple are the northern and eastern parts have the oil palm plantation area, the southern part has a village area and the western part for it’s road. The owner of Bahlal III temple is the Ministry of Culture and Tourism managed by Aceh Archaeological Heritage Preservation Center. The Bahal III temple was built during the Hindu-Buddhist period. The site of the Bahal III temple was
carried out with a description of the Drapala statues fragments as findings from the temple areas. The Bahal III temple site has many missing fragments, which are still buried beneath the surface of the land [2].

The aim of this study is knowing the under layer structural of Bahal III surface located in the Bahal III temple area, Bahal village, Portibi sub-district, North Padang Lawas district, North Sumatra province using the Wenner configuration geoelectric resistivity method and supported by geomagnetic methods to obtain more accurate results.

The geoelectric method is used to know the nature of electricity in the earth. Type resistivity geoelectric methods are very popular and and often used both in geological and exploratory surveys [3]. The research conducted by Diah, et al [4] in Bukit Carang Temple, Karanganyar explained that there were 11 anomalies of andesite rocks which were temple sites with a geoelectric value of rock resistances of 935-1,511 Ωm. The constituent rocks of the temple in the form of andesite rocks which have a greater geoelectric value of resistivity compared to the geoelectric value of the resistance of the type of hoarding material generally in the form of sand is a new sedimentary material [5].

The geomagnetic method is one of the geophysical methods generally used to know the magnetic properties and also to know the under layer geological structural surface based on magnetic field anomalies [6]. A survey with magnetic methods to determine the existence of temples was carried out by Mahfi, et al [7] at the ancient site of the Plaosan Kidul temple. Masykuri and Sismanto [8] examined the existence of Kuden temple’s stone, Klaten regency using geomagnetic methods. There are three discovery sites of andesite rocks based on total magnetic anomalous contour patterns. Riza Arfian [9] conducted a research of the identification of the Kadipaten Pasir inheritance in Tamansari Village using geomagnetic methods with andesite rocks having susceptibility values of 0.0387 (cgs units).

The next supporting analysis is XRD analysis. XRD (X-ray diffraction) is an analysis to determine the mineral content. XRD is used for samples that must be weathered. Munasir, et al [10] conducted an XRD and XRF test analysis as a source of material in Tuban and Sumenep obtained sandstone dominated with a source of quartz oxide (SiO2).

2. Research Method
The research was carried out in the Bahal’s village, Portibi sub-district, north Padang Lawas regency, using ARES Geoelectric devices, a set of PPM geomagnetic tools, elsec type 770, compass, Garmin type GPS, regional geological map, meter, stopwatch, XRD test equipment.

The place of the research was carried out in the Bahal’s village, Portibi sub-district, north Padang Lawas regency, North Sumatra province, as shown in Figure 1.

Figure 1. Research Map Location
2.1. Research Procedures

![Research Map Location](image1)

**Figure 2.** Research Map Location

3. Findings and Discussion

The observation result of geological data based on Figure 3 from the research location shows that Bahal village, Portibi sub-district, precisely the under layer surface of Bahal III temple consists of Alluvium (river clays and beaches, silt, sand and gravel, including fan deposits of landslides and canals, peat), Farmer formation (bioturbated carbon sandstone, silt stone and shale, sandstone).

![Geological Map of Research Location](image2)

**Figure 3.** Geological Map of Research Location [11]

The research area is about 58 - 66 meters above sea level with an height average of 61.84 meters above sea level. The results of the measurement of the base surface are processed using Surfer11 software to obtain the topographic contours of the research area, as shown in Figure 4.
The geoelectric method that used is the Wenner-Schlumberger method with 2 Trajectorys. The trajectory length is about 155 m using 32 electrodes with a distance between 5 m electrodes. The geomagnetic method use 60 lattice trajectories. The research measurement point as shown in Figure 5.

![Figure 4. Research Topography](image)

![Figure 5. Research Measurement Points](image)

The results of processing geoelectric data for each trajectory are shown in Figures 6 and 7. Trajectory 1 is at UTM 155288 m E, 581622 m N to 155350 m E, 581763 m N. Results of processing geoelectric data in Res2Dinv Software, trajectory known that the resistivity value is 2 $\Omega$ m up to 3368 m.

![Figure 6. Map of Pseudosection 1st Trajectory](image)

Fisrt Trajectory was dominated by alluvium rocks (surface deposits consisting of river clays, silt, sand, gravel and lumps) with a type of resistance of 100 - 800 $\Omega$ m in depth of 23 meters along the Trajectory and andesite rocks with a resistance value of 950 - 1500 $\Omega$ m. According to Telford [6] the
value of resistivity of alluvium is $10^{-800}$ Ωm. According to Diah, et al [4] regarding the identification of Bukit Carang temple site, the value of andesite rock resistance was 935 m - 1511 m. Andesite rocks was one of the constituents of temples that are below the surface of the temple (immersed temples) which are between 7-15 electrodes in a depth of 8-13 meters and a distance of 30-70 m. In accordance with the geological map, the study area was directly adjacent to the river and was dominated by alluvium rocks (Center for Research and Development of Geology, 2007).

Groundwater and clay are between alluvium rocks with a resistance value of 2-100 m in a depth of 1-27 meters. According to research conducted by Rochayanti and Rita [3] clay and ground water have resistivity values of 0-100 m.

Trajectory 2 is at the coordinates of UTM 155321 m E, 581671 m N to 155354 m E, 581760 m N.

The results of the apparent resistivity values are processed using Res2Dinv software to obtain a 2D cross-section of resistivity below the surface, then the resistivity cross-section below the surface showed vertically and horizontally in regional research, the results of the study will be illustrated by the distribution of archaeological sites that are still hidden.

In depth of 1.25 and 5 meters based on resistivity values are dominated by ground water, clay, gravel and alluvium with resistivity values of $3 - 403$ m. In depth of 10 meters, and 15 meters are dominated by types of gravel, alluvium and andesite rocks with resistivity values of $30 - 2.500$ m. In depth of 20 and 25 meters are dominated by types of clay, gravel and alluvium with resistivity values of $6 - 350$ m. Research by Rita [12] regarding the identification of below surface limestone in Langkat, it was found that groundwater on the T1 grid had a resistivity value of 0-50 m and clay on the T3 grid has resistivity values of 50-100 m.
The distance of 25 meters was dominated by alluvium with a resistivity value of 48.3-140 Ωm. The distance of 50 meters and 75 meters was dominated by clay, gravel, alluvium and andesite rocks with resistivity values of 2 - 2.500 Ωm. The distance of 100 meters was dominated by clay, gravel and alluvium with a resistivity value of 2 - 800 Ωm. The distance of 125 meters was dominated by gravel and alluvium with a resistivity value 30 – 140 Ωm.

The anomalous value that has been obtained from each measurement, the anomalous distribution pattern of the research area, namely in Bahal III temple can be seen in Figure 10.

The magnetic field anomalies found in the study area revealed that the lowest anomalies were at the point 33, it’s 300 nT and high anomaly at the point 14, it’s 380 nT.

The initial step in the form of a line section (A-A’ trajectory) from the lowest anomaly to the highest which is thought to be the source of magnetic anomaly above the anomaly contour map as shown in Figure 11.

Quantitative interpretation is needed to describe the below surface structure of measurement data. Quantitative interpretation aims to determine the lithology of the research area. Interpretation was carried out to make a geomagnetic cross section model using Mag2DC software by implicating the value of magnetic susceptibility anomaly data so that Figure 12 will be obtained that has a translation in the form of an image by showing the susceptibility and color values based on rock layers. Numerical modeling requires several parameters of the earth’s magnetic field in the research area.
which include values of IGRF (42217.7 nT), declination angle (-0.19°), inclination angle (-14.1°) and some modeling parameters.

![Figure 12. Geomagnetic Model Using Mag2DC Software](image)

Layer with value of $k = 0.034$ (cgs units) interpreted as andesite rocks in depth 25 to 60 meters. Layer with value of $k = 0.28$ (cgs units) and $k = 0.27$ (cgs units) interpreted as clay or is a type of mineral that forms in depth 10 to 60 meters. Layer with value of $k = 0.43$ (cgs units) and $k = 0.45$ (cgs units) interpreted as sandstone with a type of sedimentary rock that in depth of 25 to 60 meters.

The geomagnetic cross sectional area value as shown in Figure 10 is associated with a table of susceptibility values of rock types by Telford where the susceptibility of sandstone (0 -20) and clay (0,2). According to the geological map of the research area based on Annex 10 and Appendix 11, there are alluvium rocks (surface deposits consisting of river clays, silt, sand, gravel and lumps). Riza Arfian (2017) was conducted a study on the identification of the Kadipaten Pasir inheritance in Tamansari Village with the results of rock types that andesite rocks which had a susceptibility value of 0.0387 (cgs units).

Rock magnetic susceptibility is a fundamental physical parameter in magnetic investigation, because susceptibility is a measure of the ability of a rock to receive magnetization from the earth's magnetic field.

![Figure 13. Map of 3D Surface susceptibility in Bahal III Temple](image)

The results of testing the mineral content of rock samples using XRD can be obtained from the mineral content of rocks. Rock elements have bonded to form compounds that have different intensities. The test results using XRD devices are known that the main minerals making up rocks in the sample are SiO$_2$ 88.8%, Fe$_2$O$_3$ 8.9 %, MgO 1.7% and TiO$_2$ 0.7%.
Figure 14. The Stone Content Graph Using Match3 software

XRD graphs on temple rock samples have 13 peaks from 15 peaks which contain silica with the highest peak found in the third peak with intensity values of 1000 with the angle 26.85°. Element of MgO has the highest peak in third peak with intensity value of 925 with the angle 26.85°. Element of Fe₂O₃ has the highest peak in the fifth peak with intensity value of 90 with the angle 34°. The element of TiO₂ has the highest peak in the fourth peak with intensity value of 740 with the angle 30°.

4. Conclusion
From the findings of processing, data analysis interpretation in this research can be concluded that; (1) The results of lower surface structure of Bahal III Temple obtained using the geoelectric method of 1st and 2nd trajectories were dominated by alluvium rocks (surface deposits consist of river clays, silt, sand, gravel and lumps) with resistivity values of 2 – 800 Ωm in dept of 27 meter and andesite rocks with resistivity values of 950 - 1500 Ωm along the trajectory; (2) The result from the vertical contour of the temple’s below surface are dominated by groundwater, clay, gravel, alluvium and andesite rocks with resistivity values of 2 m to 2.500 m and laterally dominated by alluvium and andesite rocks with resistivity of 6 m to 2.500 m; (3) The below surface structure of the temple with geomagnetic method is dominated by andesite, clay and sandstone with value of k of 0.034 (cgs units), 0.28 (cgs units), 0.27 (cgs units), 0.43 (cgs units), dan 0.43 (cgs units) which is the tye of mineral that formed in depth of 10 to 60 meters with anomalies cross-section area with geomagnetic method have the lowest anomaly value at the point 33, it is 300 nT and the highest anomaly value 14 , it is 380 nT; (4) Mineral composition of temple rock samples using XRD were dominated by elements of SiO₂88.8%, Fe₂O₃ 8.9 %, MgO 1.7% and TiO₂0.7 % because Bahal III temple was built with rocks which come from Binanga river flow.

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