Optimization of Archeological Anomalies using GIS method for Magnetic and Resistivity Study at Sungai Batu, Lembah Bujang, Kedah (Malaysia)

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Abstract. Magnetic and resistivity method has become a reliable option in archeological exploration. The use of both method has become popular these day. However, both method gives different type of sensing in detecting anomalies and direct interpret from the anomalies will result large coverage area for excavation. Therefore, to overcome this issue, both anomalies can be extracted using ArcGIS software to reduce excavated coverage area. The case study located at Sungai Batu, Lembah Bujang near SB2ZZ lot expected buried clay brick monument which will be a perfect case to apply this technique. Magnetic and resistivity method was implemented at the study area where the anomalies coverage area for magnetic and resistivity is 531.5 m² and 636 m² respectively which total area of both anomalies was 764 m². By applying combine technique, the anomalies area reduce to 403.7 m² which reduce the suspected anomalies by 47.16 %. The unsuspected clay brick monument area was increase from 15.86% to 55.54% which improve the cost and labor work for excavation.

1. Introduction
Sungai Batu, Lembah bujang has been reported several of exploration related to archeological properties. The exploration have expose the clay brick monument, jetty remain and iron smelting sites [1]. This historic area was revealed by archeologist clarifying that was dating back to 110AD [2]. In an attempt to none invasively assess the number and extent of the excavation structures, several of geophysical method was implemented on the archeological focusing on clay brick monument area [3].

The use of geophysical method these day was a common practice in finding the Geophysical signature (anomalies) under the earth surface [4]. However, Archeo-geophysical was slightly different from usual interpreting soil subsurface which depend on type of buried material with principle to archeological settings. There are various type of geophysical method in finding buried structure or object which is using resistivity, magnetic survey, gravity and seismic refraction [5;6;7] Most suitable method in finding
anomalies signature is magnetic and resistivity method which give vary greatly in archeological information compared to another geophysical method [8].

Magnetic and resistivity method is highly sensitive to anomalies properties which the magnetic method tend to detect low to high magnetic properties and resistivity method detecting the resistivity value in subsurface [9;10]. However, both method give different type of anomalies due to dissimilar detecting technique. Combining both method will result in large area of anomalies to be excavate, which resulting in spending more expense and labor work during excavation. Therefore, to overcome this issue, this paper presenting on reducing the coverage area for excavation by intersecting anomalies area for both method using Geographic Information System (GIS) technique at expected buried clay brick monument near SB2ZZ lot in Sungai Batu, Lembah Bujang.

2. Theory of study

The intensity of magnetic field can be determine by magnetic method which includes material from earth crust until core. The magnetic from the geological bodies will be induce from secondary magnetic field which anomalies can be differentiate by locally creating positive and negative magnetic field [9]. The anomalies were only based on assumption from the big different of magnetic field and also targeted magnetic value for geological or archeological purposes.

For low magnetic fields, magnetization J is proportional to the magnetizing field H:

\[ J = \kappa H \]

Where \( \kappa \) is magnetic susceptibility which related to magnetic prospecting of rock parameters. The amount and susceptibilities of constituent mineral will effecting the magnetic response of rocks including the oxidation for a certain rocks.

However, in the resistivity method usually measures the earth subsurface material based on resistivity distribution [11]. Relation between some of typical rocks and soil material with resistivity value were shown in Table 1 [12]. Usually, the fresh rock have high resistivity value depends on the degree of fracturing. Since generally in Malaysia was shallow water table, the fractured were filled with ground water makes the electrical current flow easily which resulting in lower resistivity value in fractured or weathered zone [3]. As an example, the resistivity of limestone varies from 4000 ohm.m in dry condition to 2000 ohm.m. However, when the rocks are fractured and saturated with groundwater, the resistivity value reduce below than 2000 ohm.m and possibly reduce to less than 100 ohm depend of degree of weathering and water saturation.

| Material         | Resistivity (ohm-m) |
|------------------|---------------------|
| Alluvium         | 10 to 800           |
| Sand             | 60 to 1000          |
| Clay             | 1 to 100            |
| Groundwater (fresh) | 10 to 100          |
| Sandstone        | 8 - 4 x 10³        |
| Shale            | 20 - 2 x 10³       |
| Limestone        | 50 - 4 x 10³       |
| Granite          | 5000 to 1,000,000   |
3. General Geology
Jerai, Kedah. Gunung Jerai be as a geology’s reference where the type of rock here is sedimentary and granitic rock (Figure 1). The sedimentary rock around Gunung jerai area was formed from the Cambrian Age consists of sandstone or metasandstone with mixed siltstone, shale and minor conglomerate [13]. The mid-south of Kedah was recorded as marine soil area in first and second century. In year 1400 since the sea level rises, the area was form into flat landed area. [13]. However, the lithology types of the study area are majorly sandy clay covered with fine sand [3]. The sediment was carried by the river stream and deposited around this area. At present, the topography of the study area is flat landed, mostly covered by palm and rubber trees. There are a few swamps and a small river located at the eastern part of the area.

![Survey lines of magnetic and resistivity method at Sungai Batu, Lembah Bujang, Kedah.](image)

Figure 1. Survey lines of magnetic and resistivity method at Sungai Batu, Lembah Bujang, Kedah.

4. Methodology
The magnetic and resistivity survey were designed with close spacing due to archeological study which is assuming that located on shallow subsurface with a tiny object. The design location and line were distributed in grid (Figure 1) to improve accuracy in interpretation of geological and archeological features in the subsurface. A magnetic survey was implemented covered the study area with the spacing between a moving stations of 1 -2 m interval align in grid. The G-856 magnetometer equipment were used to record magnetic readings 1 minute interval time between next readings to reduce the effect of diurnal variation of the earth’s field. Magnetic need a base stations as a datum for reference point and was set up 50 m away from the study area. In processing, the gaps, instrument noise, spikes or any irregularities in raw magnetic data was monitored and inspected to reduce error in data acquisition. The correction involved diurnal variation and IGRF need to be done to produce magnetic residual. Final process in producing magnetic map by exporting data into Surfer 8 software using kriging technique to interpolate the blank area between the data.

The resistivity survey was conducted in study area using pole-dipole array with a total of 15 line (L1 – L15) were align parallel to each other with spacing of 2 m between lines. On the survey line, electrode were peged on the ground with 0.75 m spacing along the laid cable and connected with cable takeout
using jumper. Cable were connected with ES10-64 electrode selector and data acquired by ABEM SAS4000 instrument which pole-dipole array has been programmed. The collected data will be created in “.DAT” format which can be read by Res2Dinv software. The inversion result were produce in Res2Dinv and displayed in 2-D pseudo-section image.

5. Results
Figure 2 shows the result of magnetic and resistivity anomalies in residual map which suspected as baked clay bricks monument. Red dotted point in Figure 2a show the magnetic survey location and black line indicate the most distinct anomalies [15]. The magnetic map gives magnetic value from -70 nT – 180 nT. Basically, the interest anomaly which is clay brick material have high magnetic content, which gives high magnetic anomalies indicated the possible of buried baked clay brick monument at survey site. From the result obtain, the value of high magnetic value was range between 37.5 – 180 nT. These magnetic value detected according to contrast of magnetic (clay brick material) with the surrounding material mostly is sandy clay.

Figure 2b show the resistivity anomalies map which finalized from previous study [16]. The anomalies of baked clay brick monument were interpreted based on resistivity value of all fifteen resistivity survey lines. It was spotted that the anomalies was located between 0-1 m depths with resistivity value of more than 3500 ohm.m. Then, the suspected baked clay brick monument were mapped based on resistivity value (>3500 ohm.m) to see the anomalies pattern.

![Figure 2](image_url)

**Figure 2.** Suspected baked clay bricks monument mapping at SB2ZZ site, Sungai Batu, Lembah Bujang based on a) Magnetic anomaly and b) Resistivity anomaly.

Both of magnetic and resistivity anomalies map were digitized using ArcMap 10.2 to synchronized and locate the real anomalies on the study area. However, both maps gives a different anomalies location when it is overlap each other. The general cause of this situation is due to different method in data collection where both parameters is measuring different type of properties. Moreover, the contrary anomalies also caused by contouring effect which happen in interpolation process where the unknown data in between the measured value were interpolated based on known data to predict the unknown value, it will creating the uncertainty value between them.
Therefore, the error in anomalies prediction were reduce using intersect technique in ArcMap 10.2 software which resulting the optimization of anomalies based on magnetic and resistivity value. Figure 3 show the optimized anomalies result (red colour) which from the combination of magnetic and resistivity anomalies. The coverage area of magnetic anomalies is 531.5 m² and resistivity anomalies is 636 m² where when combine both area become 764 m². However, the coverage of study area is 908 m² and it just reduce only 15.86% of unsuspected area, which not reducing much for the excavation work. By intersecting both anomalies using intersection method, the anomalies were reduce to 403.7 m² which increase the unsuspected area to 55.54%. Hence, the anomalies area was reduce from 764 m² to 403.7 m² which is 47.16 % reduction from the original anomalies.

Figure 3. optimized anomalies area based on Magnetic and resistivity anomalies.

6. Conclusion
The optimization of anomalies of magnetic and resistivity method has been carried out can be a useful technique in archeological prospection. It is proven that this technique has reduce the anomalies area from 764m² to 403m² immediately will reduce the cost and time consuming for archeological exploration. However, it is recommended including more geophysical method and other site investigation to improve anomalies optimization hence will reduce the misinterpretation.

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