Integration of Electrical Resistivity and Seismic Refraction using Combine Inversion for Detecting Material Deposits of Impact Crater at Bukit Bunuh, Lenggong, Perak

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Abstract. Both electrical resistivity and seismic refraction profiling has become a common method in pre-investigations for visualizing subsurface structure. The encouragement to use these methods is that combined of both methods can decrease the obscure inherent to the distinctive use of these methods. Both method have their individual software packages for data inversion, but potential to combine certain geophysical methods are restricted; however, the research algorithms that have this functionality was exists and are evaluated personally. The interpretation of subsurface were improve by combining inversion data from both method by influence each other models using closure coupling; thus, by implementing both methods to support each other which could improve the subsurface interpretation. These methods were applied on a field dataset from a pre-investigation for archeology in finding the material deposits of impact crater. There were no major changes in the inverted model by combining data inversion for this archetype which probably due to complex geology. The combine data analysis shows the deposit material start from ground surface to 20 meter depth which the class separation clearly separate the deposit material.

1. Introduction

Electrical resistivity and seismic refraction method has become a common technique in site investigation to discover the subsurface profile without harming the environment [1]. The intention in using these two methods is to integrate both of methods which can reduce the ambiguity inherent from both method. There is some weakness in each method for example that the electrical resistivity will fail to recognize low contrast gap between low resistivity value such as shale and clay, but seismic refraction could differentiate it due to dissimilar velocities [2]. Equally for seismic refraction if low velocity was underlain by high velocity material such as boulder area where it could be a problem, but can be differentiate it by electrical resistivity method [3]. Otherwise, the interpretation of subsurface can be improve by combining inversion data from both method by influence each other models using closure coupling.

Geophysical inversion for both electrical resistivity and seismic refraction method can be done by several available software packages individually, but the result are limited possibilities to combine these two types of method in the same inversion [3]. In this study, algorithm has been made by
combining inversion data based on same coordination of data point. Every combination data point will be sort based on high, medium or low seismic refraction and resistivity value. The aim of this study to test the algorithm and to evaluate the viability of this method, thus can improve the geology interpretation.

2. General Background of Study Area
Study Area was chosen at Bukit Bunuh due to presence of meteorite impact collision with earth surface which produce a bowl-like shape crater [4]. It suspected as meteorite impact crater due to presence of more than 10000 surface suevite rocks scattered around the area caused by hypervelocity impact [5]. However, weathering processes covering the impact shape, causing the crater fade away filled by weathered earth material [6]. It is the perfect opportunity to implement combine inversion technique to discover the material deposits signature.

Bukit Bunuh located at the upper part of Perak state near Lenggong town. Bukit Bunuh lies between two mountain ranges; Bintang and Titiwangsa Ranges and made up of quaternary sediment and small lithology unit of tertiary tefra ash and meta-sediments [7]. Figure 1 shows the Lenggong area was underlain by Acid intrusive rock which from Jurassic to carbonaceous age coming from Bintang Range at Lengong West and overlain by Limestone and Marble [7].

![Figure 1. Geology map of Bukit Bunuh, Lenggong, Perak [7.]](image-url)
3. Methodology

3.1. Data Acquisition
The electrical resistivity data was carried out using ABEM TerrameterSAS4000, and seismic refraction was acquired using ABEM Terraloc. The spacing of electrodes was 5 meters and for geophones was 5 meters spacing where the coordination was recorded using differential GPS with ground corrections. Both method was using roll-along measurement. The survey lines were conducted from North to south area across the vegetation area both seismic refraction and electrical resistivity (figure 2). The length of profile is 300m which the electrical resistivity need 2 spread with 200m overlapped and seismic refraction need 3 spread with 5 meters overlapped. Electrical resistivity data was measured using 41 electrodes using pole dipole protocol and seismic refraction originates from 7 shots point with 24 geophones for each spread.

![Survey line of electrical resistivity and seismic refraction at Bukit Bunuh, Lenggong, Perak.](image)

3.2. Inversion
The inversion of each electrical resistivity and seismic refraction model was done independently for every method [8]. There are several methods available for the interpretation of seismic refraction survey data (e.g. [9], [10], [11]). The standard method in interpretation of refracted arrivals by utilizing first breaks only in a small-scale refraction surveys, the refraction trace uses amplitudes and first-arrival travel times to generate time sections in a full trace processing [12].

Seismic refraction data were analyzed using the software programs FirstPix (ver 4.21) and Seis@Opt@2D (ver. 3.5), where the first arrival travel times was picked using FirstPix software involves the creation of an initial velocity model, and then iteratively tracing rays through the model, comparing the calculated travel times to the measured travel times, modifying the model, and repeating the process until the difference between calculated and measured times is minimized and the tomographic image was using SeisOpt@2D to visualize the subsurface section.

Inversion for electrical resistivity method was completely automatic using RES2DINV programs and user does not need to supply a starting model. The smoothness-constrained Gauss Newton least squares inversion method was used in RES2DINV [13] to create a 2D electrical resistivity model from apparent resistivity data. Optimum inversion can be automatically being done by the program and can be modified manually base on inversion parameters.

In combine inversion, the inversion result for both seismic and resistivity will be sorted by low, high and targeted value of seismic refraction and resistivity. Each combination of different algorithm
value will be classified as one class. There was 9 possible classes was created as shown in Table 1. Image will be projected on the 2D pseudo-section align with the coordination gathered by seismic refraction and resistivity image.

4. Results and Discussion
The result obtain for seismic refraction and resistivity was generated in 2D section image (Figure 3). Both result was created after the inversion process where the seismic refraction image was based on compressional wave velocities value, \( V_p \) (m/s) and resistivity image was created based on resistivity inversion value, \( \rho \) (ohm.m). The color legend was set as default value and it works as indicator to velocity and resistivity value.

Figure 3a shows the seismic refraction image where the overall velocity is from 600 – 4600 m/s. Since the geology of the study area was granitic rock, the velocity of weathered granite starts between 1200 – 1700 m/s which mean the soft soil for this area located at 70 – 75 m elevation [4]. Figure 3b shows the electrical resistivity image range 0 – 25000 ohm.m of resistivity value. The resistivity value of low to highly weathered granitic rock in range 900 – 2500 ohm.m where it located around 65 – 70 m elevation in the image [4]. It shows some similarities between these two methods which generally be seen there was a 2 major layer which is soft soil at top and hard layer at bottom. However, both method give different image section where in average viewer, it seems to be similar image and both method have different ambiguity and weakness in interpreting the geological aspect.

![Figure 3. 2D section image of (a) seismic refraction and (b) electrical resistivity.](image)

The result of combine inversion as seen in figure 4 was produce a 2D model contain of nine main classes referred to Table 1. The number of classes was classified as a combination view for both electrical resistivity and seismic refraction. The class was determine based on previous research where the optimum velocity and resistivity was finalized [4]. This paper focused on material deposit inside
crater of impact crater at Bukit Bunuh where the velocity value in range 275 – 2100 m/s and resistivity value in range 100 – 5000 ohm.m which fall in class 5 (light green). Result shows the thickness of deposit material (light green) about 15 – 20 m thick. The separation of class was shown in figure 5 plotted in scattered graph. The three-main class were dominating which is class 5, 8 and 9 with percentage frequencies 20.8%, 27.4%, and 42.8% respectively.

**Figure 4.** Combine inversion class model derived from seismic refraction and electrical resistivity, 9 classes.

**Table 1.** List of classes for combine inversion image.

| CLASS | VELOCITY, M/S | RESISTIVITY, OHM.M | COLOR |
|-------|---------------|-------------------|-------|
| 1     | 0-374         | 0-99              |       |
| 2     | 0-374         | 100-5000          |       |
| 3     | 0-374         | >5000             |       |
| 4     | 375-2100      | 0-99              |       |
| 5     | 375-2100      | 100-5000          |       |
| 6     | 375-2100      | >5000             |       |
| 7     | >2100         | 0-99              |       |
| 8     | >2100         | 100-5000          |       |
| 9     | >2100         | >5000             |       |
Figure 5. Illustration of respective classes are formed to their seismic velocity and resistivity from cross-plot inverted section.

5. Conclusion
Combine inversion in this study case was obviously beneficial due to simple geology of the case investigation. The class separation analysis produces an additional mechanism for interpretation, highlighting the deposit material inside the impact crater which have high influence in archeological exploration. Interpretation of the seismic refraction and resistivity with help of combine inversion analysis however does approve what skilled interpreter could presume. From the result can conclude the alluvial deposition which can improve interpretation in finding the ancient river. This represent that combine inversion analysis shall be a useful technique for interpretation which has capability for future development.

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