Sub-surface identification of iron sand in Lamreh, Aceh Besar using very low frequency method

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Abstract. This work was studied about 2D Sub-Surface Identification of iron sands in Lamreh, Aceh Besar by using Very Low Frequency method based on Resistivity mode (VLF-R). The aims of the research; (1) Predicting 2D sub-surface of iron sands resistivity in Lamreh based on VLF data. (2) Conducting 2D sub-surface identification measurement data of iron sands. VLF data were measured into 3 lines, by the first line was 250 meters and the second line was 120 meters and the third lines was 100 meters. 2D modelling in VLF-R was conducted by using 2LAYINV electromagnetic inversion program. Inversion process showed 2-iron sands-conductivity-zone, where the resistive layer in depth was covered by conductive layer on it. The conductive layer was expected as clay being rich of water content by resistivity rate at 10 – 100 Ωm. Resistive layer was expected as cap rock by resistivity rate at 20000 – 40000 Ωm.

1. Introduction

In Indonesia, several studies related to iron sand are also actively being carried out. As previously reviewed [1] that iron sand deposits can have several magnetic minerals such as magnetite (Fe3O4), hematite (α-Fe2O3), and maghemite (β-Fe2O3). These minerals have the potential to be developed as industrial materials. Magnetite, for example, can be used as a base for dry ink (toner) in photo copiers and laser printers [2,3]. While maghemite is the main material for cassette tapes. The three magnetic minerals above can also be used as dyes and mixtures (filters) for paints and basic materials for the permanent magnet industry [6,7].

To find out more about the subsurface structure of iron sand on the coast of Benteng Lubok, Lamreeth Village, Aceh Besar, it is necessary to conduct research using one of the geophysical methods, namely the Very Low Frequency (VLF) method which is part of the electromagnetic method [4]. This method utilizes electric and magnetic fields originating from low frequency radio transmitters which can provide differences in subsurface electrical conductivity values.

The VLF electromagnetic method utilizes the electromagnetic field generated by the large power VLF radio wave transmitters operated for military purposes, especially for communication with submarines [5]. The VLF method utilizes low frequency waves (15-30 kHz). In this study, the VLF method is used to estimate the electrical conductivity of subsurface geological structures and to model subsurface structures in the coastal area of Benteng Lubuk, Lamreh Village, Aceh Besar.

This research study in depth the subsurface structure of iron sand using the VLF method on the coast of Benteng Lubuk, Lamreh Village, Aceh Besar with the hope that this iron sand can be utilized and increased its economic value as well as additional data base information for the local area. The research objective was to predict the 2D iron sand subsurface structure model in the coastal area of Benteng Lubuk, Lamreh Village, Aceh Besar based on VLF-R data.

2. Materials and Method

The research work was conducted in 2 phases, namely data measurement in the field and data processing. The data measurement took place in the coastal area of Benteng, Lamreh Village, Mesjid Raya District, Aceh Besar District.
Figure 1. Survey Area at the coastal area Lamreh, Aceh Besar

The Detektor T-VLF was used in this investigation. The apparatus supported with i.e. battery 1.5 volt, electrode, GPS and Software 2 Layer Inversion (2LAYINV). After data acquisition was carried out in the field, the data processing took place in the geophysical laboratory, Department of Physics, Mathematics and Natural Sciences, Syiah Kuala University using such software.

Next step, the geological information and survey area for investigation were collected. Then, a measurement path was made, with track 1 along 250 meters and track 2 along 120 meters and a third track along 100 meters marked using yellow spray paint, for resistivity distance between measurement points as far as 10 meters.

The 2LAYINV program is used to interpret the geophysics and VLF-R electromagnetic data (resistivity and apparent phase) which was measured along a single pass at a single frequency. The inversion was made separately for each data point using 2 layers of the earth with the 1 D model. The program tools adjust the interpretation of the thickness and resistivity of the relatively less resistive (soil) layer and the resistivity variation of the bedrock surface. It should be noted that the inversion model is still 1D and the result of the interpretation produces a 2D cross section of the 2D resistivity distribution.

3. Results and Discussion

The results of field measurements with resistivity mode are obtained in the form of pseudo resistivity and phase values from each measurement point and each frequency. The apparent resistivity and phase values are input data for 2D modeling of structures beneath the surface of the area. 2D modeling of VLF-R data was carried out using the electromagnetic inversion method program developed by Markku Pirttijärvi [15], known as two-layer inversion (2LAYINV). With this modeling method, calculations are directed to obtain a model of the two layers of the earth below the surface measured along one profile at one frequency only. Modeling was also carried out using the Surfer program. The model obtained after the inversion calculation process using 2LAYINV is as follows:
The model obtained from inversion calculations using 2layinv software on line 1 (Figure 1) explains the resistivity value based on inversion modeling so that the 2 layer form is obtained which is the result of data inversion. The results of data inversion from the first frequency resulted in a model (Figure 4.2) with a Root Mean Square (RMS) data error of 11.28% and an RMS model error of 0.41%. The RMS data error value and the large model error when compared to the second frequency are due to the very large fluctuation of the phase value from one station to another. The value of the phase measured (phase measured) is not good so that the phase computed (phase calculated) can not be matched. The RMS error data is obtained from the comparison between the calculation data and the measurement data.

In the model (Figure 1) the high phase will have a large conductivity and vice versa, the low phase value will have a high resistivity value. So, the phase value is directly proportional to the conductivity value and inversely proportional to the resistivity value. In the 1D assumption the phase value> 450 indicates a conductive layer structure at a certain depth, on the other hand, the phase value <450 indicates a layer structure that is resistive in a material. This is because the phase for a homogeneous earth is constant, which is 450 which is the phase difference between the electric and magnetic fields, in the 1D assumption.

In the electromagnetic inversion method for 2D modeling, it uses field measurement data, namely the resistivity and phase values. From the model (Figure 1), it can be seen that the first layer at the measurement point of 0 - 40 m is very conductive (low resistivity value) to a depth of 20 m with a resistivity value ranging from 15 - 20 Ωm (in the figure shown on a logarithmic scale). At a measurement point of 40 - 110 m with a depth of about 10 m, it has a smaller resistivity value between 15 - 30 Ωm than at a measurement point of 0 - 40 m. The value of the resistivity in this layer is between 10 - 30 Ωm.

This small resistivity value is estimated because around the 40 - 100 m measurement point there is iron sand or sea water intrusion. It is difficult to distinguish iron sand anomalies from sea water intrusion because the resistivity values are very close. In this first layer, it is also estimated that there is an anomaly of iron sand or sea water intrusion [8].

In the second layer of the model (Figure 1), it can be seen that at the measurement point 40 - 100 m is very conductive (low resistivity value) compared to the measuring point 0 - 40 m and 150 - 250 m. The conductivity value in the second layer is between 10000 - 20000 Ωm (in the figure shown on a logarithmic scale) and high resistivity is estimated due to the presence of materials that have low conductivity such as iron sand or sea water intrusion.

The frequency of the two models (Figure 2) is the result of the inversion using a frequency of 22200 Hz. Compared with the model at the first frequency, it is clear that the difference in penetration depth is caused by the smaller frequency selection (first frequency <second frequency) [9]. The results of the inversion at the second frequency with the RMS error data 29.99% and the RMS model error 0.34%. The RMS data error at the second frequency is greater than the first frequency. It is estimated that the comparison between the calculated data and the measurement data is no better than the data at the first frequency.

**Figure 2.** The model obtained after calculating the inversion on line 1 with a frequency of 15975 Hz (first frequency).
frequency. For the RMS model the error at the second frequency is smaller than the first frequency with a difference of 7%.

The first layer is clearly visible with the color shown on the logarithmic scale which is very resistive with a penetration depth of up to 10 meters. The resistivity value in this layer ranges from 0 - 15 Ωm. In the second layer, it is clearly visible with the color contrast shown on a very conductive logarithmic scale [10]. The resistivity value in the second layer (Figure 2) is between 30000 - 400000 Ωm (shown in the figure on a logarithmic scale). Important that, the current flow in the sub-surface has an increasing at initial, then a decreasing with the increasing of electrode separation. This is due to the presence of a multiple conducting and resistive structures at depth [11-14].

Some works were also successfully used in the delineation of the subsurface conductivity of geologic materials in a sedimentary basin for assessment of groundwater quality. The study has demonstrated that the VLF-EM geophysical technique like electrical resistivity methods can be used separately for the mapping of subsurface geology in a sedimentary environment [16].

4. Conclusions
It can be drawn that the comparison of the resistivity model in the first layer is very conductive with a resistivity value of 0-20 Ωm. The results of the inversion at the second frequency with the RMS error data 29.99% and the RMS model error 0.34%. The RMS data error at the second frequency is greater than the first frequency. It is estimated that the comparison between the calculated data and the measurement data is no better than the data at the first frequency. For the RMS model the error at the second frequency is smaller than the first frequent is difficult to distinguish the resistivity value between iron sand and sea water intrusion in the model generated by the electromagnetic inversion method and modeling using a program.

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