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Modeling of Floating Time Domain Electromagnetic Method to Detect Dissolved Sediment

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Abstract. In hydrology context, sediment can be interpreted as inorganic and organic material that is transported by, suspended in, or deposited by streams. It is important to know the function of soil, stream discharge, land-cover features, weather conditions and land-use activities. Sediment load carried by streams and rivers can be composed either of fine materials, mostly silts, and clays, or coarse materials such as sand. One product of sediment is dissolved load consists of indistinct material in solution moving downstream. It is produced by chemical weathering processes and does not move out of the water. To investigate the dissolved sediment, we have applied the floating of Time Domain Electromagnetic (TDEM) method. The acquisition of TDEM data has been performed use tires and small ship as innovation measurements. The calculated data model using Occam and Marquardt Algorithms. The responses of data show the sedimentation has less resistive compare the surrounding structures. This innovation is very helpful to know the environmental condition, especially in the water.
Keywords: Dissolved sediment, floating loop, Time Domain Electromagnetic

1. Introduction

Until recently there has not been a lot of discussion about the use of geophysical techniques to detect dissolved sediment. The sedimentary environment can be occurred on the land or under the water based on the physical and chemical processes that are active and the organisms that live under those conditions [1]. Seismic and gravity methods were used commonly for dissolved sediment mapping purposes. Those methods involve measurement of specific parameters generated by the anomalies. Dissolved sediments determined by conductivity contrast from others. The conductivity anomaly was generally accepted as the best indicator of the sediment. But it became difficult to give good results with just conductance parameter.

Time domain electromagnetic (TDEM) method also can be used to "see" dissolved sediments because of its sensitivity in conductivity contrast. It was more effective to use because the acquisition technique is simple and the instrumentation costs relatively cheaper, rather than seismic method. This method relies on detection of induced voltage generated by the variance of the earth secondary magnetic field.

Unfortunately, the potential of TDEM method was not fully realized for aquatic environments and sediment mapping beneath it because this method still focused on finding conductivity anomalies on the land. TDEM method particularly has not been applied in deposit exposes in which located under the water. It requires instrument modification, and forward modeling processes to assure the effectiveness of the method for beneath the water sediments detecting.

This paper illustrates the configuration that used to modify the TDEM instruments so that it stays above the water when acquisition processes. Also, it presents some synthetic models of layers that calculated by Occam [2] and Levenberg-Marquardt [3,4] algorithms. The algorithms have allowed us evaluating the similarity of forward modeling and calculated data model. The resemblance indicates the applicability of TDEM method to detect dissolved sediments in which lied underneath the water.

2. Method

2.1. Time Domain Electromagnetic

TDEM methods need a transmitter to induce time-varying current into a transmitter loop. The current of transmitter loop generates a primary magnetic field that forms a smoke ring [5,6] into the subsurface. When the current finds different subsurface materials, it induces eddy currents that generate secondary magnetic field based on Maxwell equations. This secondary magnetic field is recorded in receiver at specific time periods.

The skin depth is denoted as a depth when the amplitude is dissipated by 1/e or about 37% of the initial rate. It is used as an estimation of the exploration depth of the electromagnetic schemes [7]. The skin depth of time domain (δ_{TD}) is expressed by

$$\delta_{TD} = \sqrt{\frac{2t}{\mu\sigma}}$$

The depth is illustrated as the maximal depth in which a specified object can be observed during the investigation.

2.2. Modification Design

Design modification made by using pipes, tires, and straps that are formed with a central loop [8,9] configuration of transmitter and receiver. We used pipes with its size and length of 2 inches and 1 m, respectively. These pipes can be combined with other pipes and are easily be adjusted. Straps used to strengthen the connection of pipes, so that are not easily separated. Once the pipeline is ready, then the tire is installed on each side of the circuit pipes as necessary. The tires will support the pipeline over the water. Figure 1 shows TDEM modification design on the water with combined pipes with a size of transmitter and receiver loop is 6 x 6 m^2 and 5 x 5 m^2, respectively.

Figure 1. Modification design of floating TDEM.

The assembled pipeline used to form a loop of transmitter and receiver and insert the cables into the pipeline. In each pipe used such of rubber to assure that the cables keep straight inside the pipeline. Detail of the pipe shown in figure 2. The tool of TDEM will remain in dry place (or small ship) during the measurement.

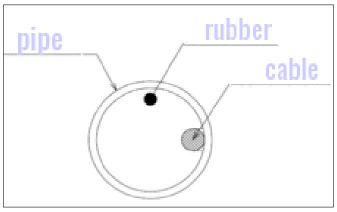

Figure 2. Detail of cable clamp inside the pipe.

2.3. Numerical Simulation

To find out the applicability of the proposed design, a forward modeling and data inversion is conducted. In this case, a generalized stratigraphic sequence [10] off the west coast of Peninsular Malaysia is chosen to become the synthetic model. The model consists of 6 layers with five different geological layers: soft marine mud, sandy clay, clay, gravels or pebbles, and granite bedrock. We assume there is a presence of secondary tin deposits within gravels. The chosen lines of the synthetic model and the physical parameters [11] (estimation value) used in forward modeling process are shown in figure 3 and table 1, respectively.

3. Results and Discussions

The resistivity models (Line 1, 2, and 3) from Occam inversion can be viewed in figure 4. The resistivity model is taken from two order smoothness derivatives at three different lines using starting model with homogeneous resistivity and thickness of 5 Ωm and 10 m, respectively, computed for times of 1 µs and 1000 µs. The first and second order smoothness derivatives of data mostly fitted from 5 - 90 m depth.

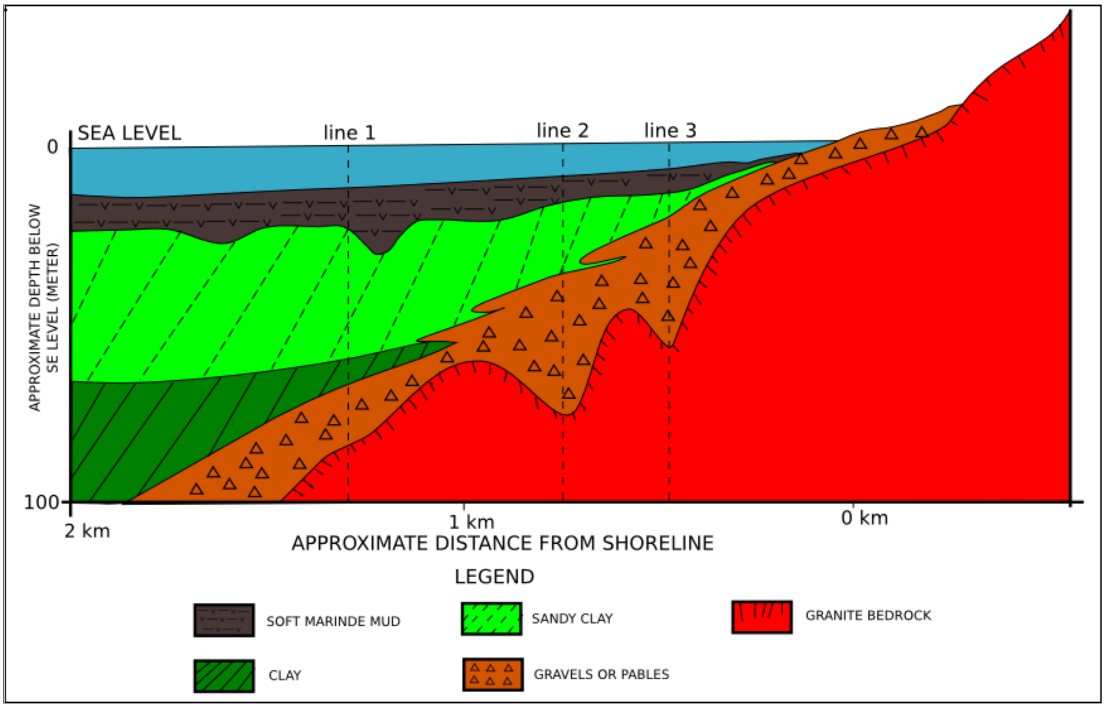

Figure 3. Generalized stratigraphic sequences off west coast Peninsular Malaysia (modified [10]).

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Table 1. Physical properties of synthetic model

Material	Resistivity (Ωm)	Thickness (m)		
		Line 1	Line 2	Line 3
water	5	10	10	8
Mud	50	10	10	10
Sandy clay	150	35	20	7
Clay	100	10	-	-
Tin deposits	20	15	35	35
Granite bedrock	1000	∞	∞	∞

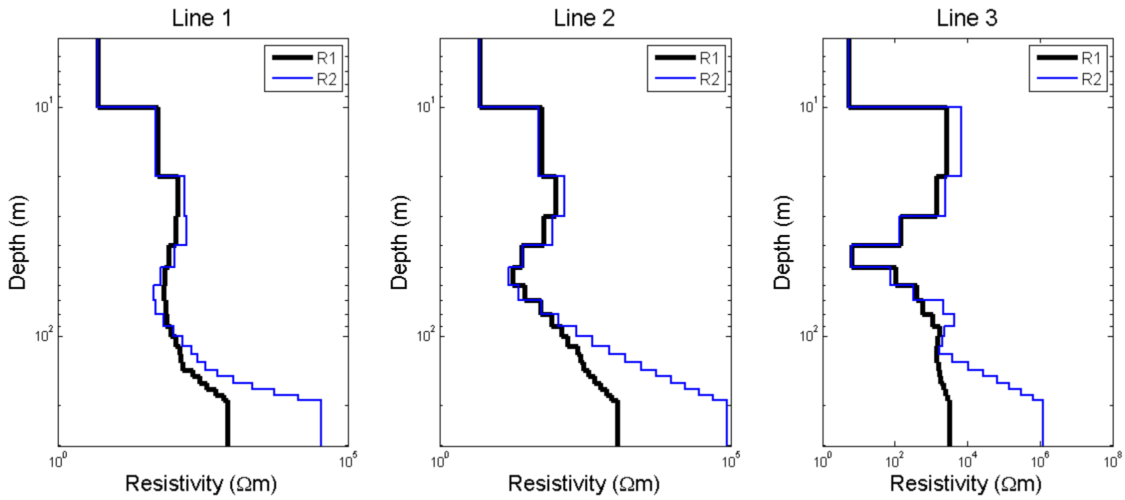

Figure 4. The first (R1) and the second (R2) order of smoothness restrictions of Occam inversion at line 1, 2, and 3.

In the case of Marquardt inversion, the data inverted by using four layers of starting models with homogeneous resistivity and thickness of 10Ωm and 10m, respectively. In this stage, the correlation of measured and calculated data has a good fitting and RMS values are varying from 0.3 – 2%. Figure 5 shows the resistivity models of Occam and Marquardt inversion. It shows that the Marquardt and Occam models are mostly suitable with each other. The most important thing is the correlation models can show the presence of secondary tin layer.

4. Conclusion

The proposed design can be used to implement geophysical measurements of TDEM method on the water. The method has good resolution, particularly for mapping conductive layers in resistive sections. The inversion results of the synthetic models proved that the numerical simulation of the design is capable of detecting dissolved sediments in which occurred beneath the water. The dissolved sediments (secondary tin deposits) have less resistive layer comparing to the other layers. The presence of deposits with a conductive layer (20 Ωm) can be seen at a depth of ± 60 meters, 40 meters, and 30 meters for line 1, line 2, and line 3, respectively. The result of this study concluded this innovation is very helpful to know the environmental condition, especially in the water.

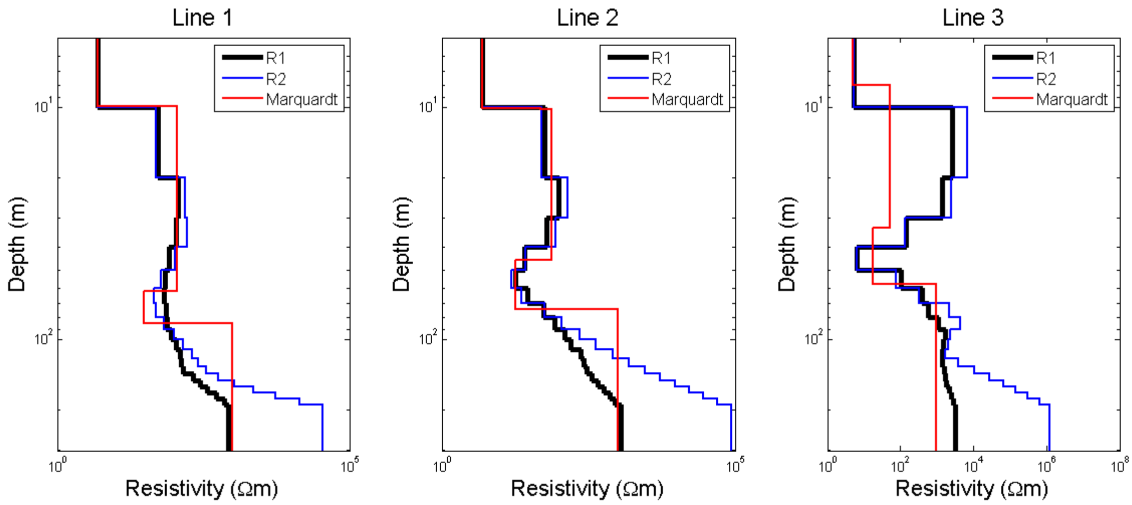

Figure 5. Marquardt and Occam's (first (R1) and second (R2) order of smoothness constraints) inversion models for line 1, 2, and 3.

Figure 5 shows the resistivity models of Occam and Marquardt inversion. It shows that the resulting Marquardt and Occam models are mostly suitable with each other. The most important thing is the correlation models can show the presence of secondary tin layer.

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