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# NOTES AND CORRESPONDENCE

# Efficiency of a Marine Towed Electrical Resistivity Method

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## ABSTRACT

In contrast to marine sediments, because of large electrical resistivity anomalies found in sulfide deposits and methane hydrates, resistivity measurements such as marine towed electrical resistivity (MTER) might be a feasible method for discovering those natural minerals. To determine the feasibility of the MTER method we examined arrays consisting of a pole electrical dipole (PED), vertical electrical dipole (VED) and horizontal electrical dipole (HED). The VED array showed a maximum difference in electric fields of 36% and 105% in the resistive and conductive models, respectively, while the PED and HED arrays yielded worse results of around 13% to 19%, respectively. The VED array showed a higher difference in electric fields than both the HED and PED arrays in the two models. Therefore, we suggest that a VED array with a large electrical current would be most conducive leading to the discovery of such minerals during MTER surveys.

Key words: Marine towed electrical resistivity, DC resistivity survey, Sulfide deposits, Methane hydrates, Forward modeling

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## 1. INTRODUCTION

A marine towed electrical resistivity (MTER) survey is an extended version of the traditional direct current (DC) method used on land. Since the first MTER survey with submersible passive electrode cables was carried out by Francis (1985), MTER has become an effective geophysical tool to discern sulfide deposits (Francis 1985; Von Herzen et al. 1996) and methane hydrate (MH) (Goto et al. 2008) due to the large contrast in electrical resistivity in comparison to most sub-seafloor sediments. However, previous studies have mostly used horizontal arrays. These configurations make it difficult for electrical current to penetrate vertically downward into the sediments within conductive marine environments (Um and Alumbaugh 2007). However, the issue of ameliorating this inefficiency has not been mentioned in previous studies addressing this method (Francis 1985; Von Herzen et al. 1996; Um and Alumbaugh 2007; Goto et al. 2008). The task of creating vertical electrical fields beneath a seafloor has become one of the critical problems for the successful application of the MTER method.

## 2. NUMERICAL FORWARD MODELING

To examine the responses of the different orientation arrays in the MTER method, a 3D forward algorithm developed by Spitzer (1995) is used. We consider three arrays of PED, VED, and HED for the feasibility test (Fig. 1). The dipole offset of the PED is fixed at 3990 m; the long dipole offset is considered a point source, while the VED and HED arrays are fixed at 20 m. The background model includes seawater (0.3 ohm-m, 4000 m in thickness) and a sedimentary layer (1 ohm-m, 35 m in thickness). These two resistivity values are exchangeable in the model as in Fig. 1. The assumptive resistive layer (10 ohm-m, 25 m in thickness) is for MH, and the conductive layer (0.2 ohm-m, 25 m in thickness) is for the sulfide deposit. The electrical current used for each of the arrays is 20 amps.

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## 3. INTERPRETATION

Figure 2 shows the comparison of electric fields and their moving orientations between the resistive and conductive anomalies for all the arrays. The densities and orientations of the different electric fields are obviously influenced by the anomalies beneath the seafloor. In the PED array, the electric fields show no vertical component returning to the seafloor (Fig. 2a). Weaker vertical electric fields can be found in the case of the resistive anomaly (Fig. 2b, left), and stronger in case of the conductive anomaly for the VED array (Fig. 2b, middle), while we see a minority of vertical electric fields run through the conductive anomaly and then back to the seafloor in the case of the HED array (Fig. 2c). Therefore, the density of vertical electric fields returning to the seafloor would determine the efficiency of the MTER method.

We also analyze the difference in electric fields with and without anomalies for the arrays represented in the

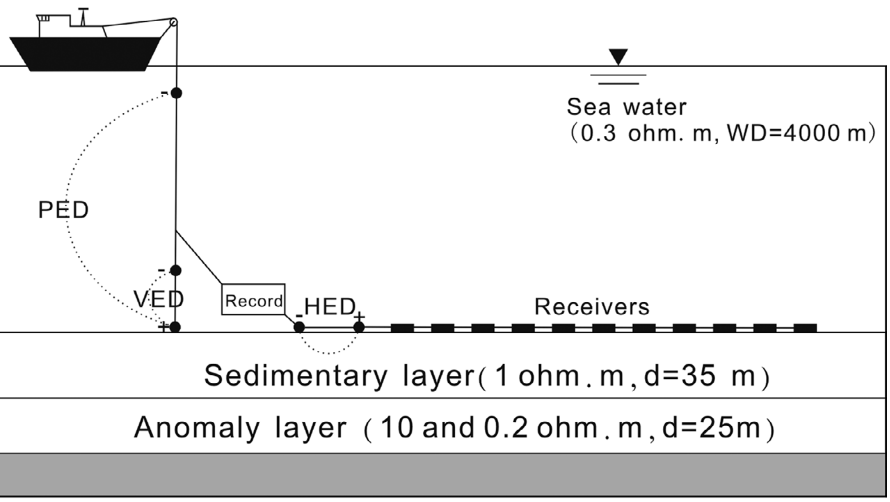


Fig. 1. Configuration of marine towed electrical resistivity system with the VED, PED and HED arrays. The solid circles indicate electrical poles, and the solid squares are potential receivers. WD: water depth, d: layer thickness.

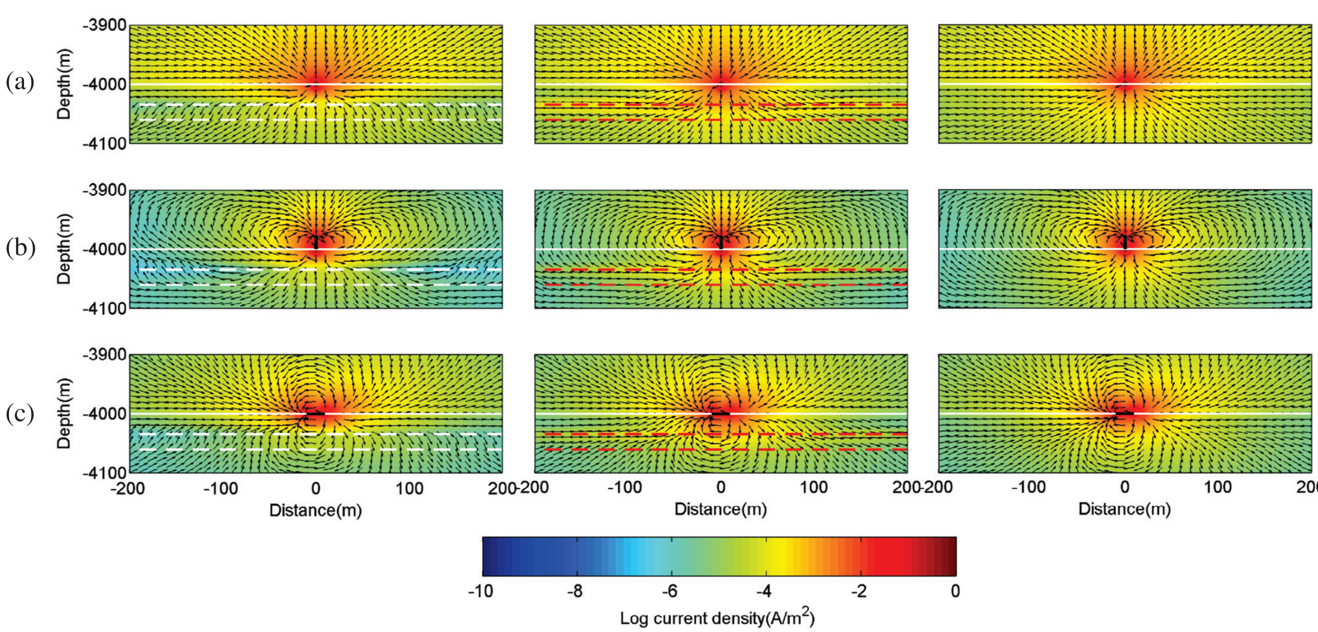


Fig. 2. Comparison of electric fields and their moving orientations. The left panel shows the resistive model (MH); the middle panel shows the conductive model (sulfide deposit); the right panel shows background model with (a) PED, (b) VED, and (c) HED arrays. The white solid line indicates the seafloor, the white and red dashed lines indicate the thickness of resistive and conductive layer, respectively. The black arrows show the orientations of electric fields.

above model as shown in Fig. 1. For the resistive model (MH), the difference in electric fields is significantly reduced in all the arrays, and the HED and PED curves appear similar to each other at around 13% to 16% at ±120 to ±150 m (Fig. 3). The VED array displays the highest difference in an electric field of 36% compared to the HED and PED arrays of around ±120 m. For the conductive model (sulfide), the maximum difference in electric field in the VED array is 105% at ±120 m, while in the HED and PED arrays it is 19% and 16% at around ±120 to ±150 m, respectively (Fig. 3). The summarized results are shown in Table 1. These results indicate that the VED array would probably provide the highest sensitivity to detect either resistive or conductive anomalies.

## 4. CONCLUSION

This study suggests that the VED array with a large electrical current would provide a sufficiently high enough efficiency to investigate shallow resistive and conductive anomalies beneath the seafloor. The MTER method is sensitive to conductive rather than resistive anomalies. Moreover, according to the actual MTER experiment (Goto et al. 2008), noises induced by tidal flow, erroneous electrode spacing, altitude change from the seafloor, topography effect, and cable vibration would cause poor data quality. The noise level is around 10% - 15% of the measurements, which is very close to the difference in electric fields of the PED and HED arrays (13% - 15%). Therefore, the VED array could improve data quality considerably due to the higher difference in electrical fields (36% - 105%) compared with the noise level. However, the vertical electric dipole would be tilted during the ship towing movements or affected by strong current flow. The vessel movements must be stopped or slowed down until the vertical status has been reached, again. This issue could increase the operating time and slow current marine research. Thus, the VED system should still be improved for efficient field work in the future.

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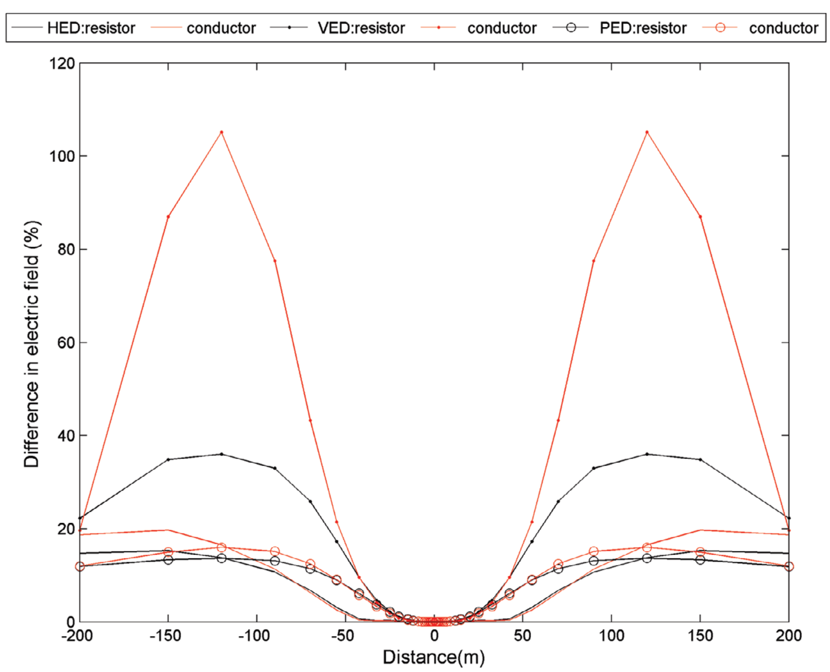


Fig. 3. The difference in electric fields of the PED, VED, and HED arrays with and without anomalies for the model as shown in Fig. 1.

Table 1. A summary of the differences in electric fields for all the arrays.

| Diff. in electric fields / Array types | Max. (%) (resistive model) | Max. (%) (conductive model) | Distance (m) |
|---|---|---|---|
| PED | 13.68 | 16.00 | ±120 |
| VED | 36.01 | 105.02 | ±120 |
| HED | 15.30 | 19.70 | ±150 |

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