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Topographic Effect of Transient Electromagnetic Responses

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ABSTRACT

A three dimensional body is designed to simulate the valley shaped topography. Transient responses are calculated for topography at source location and at receiver location respectively. Modeling results are shown by relative anomalies in contours. The behavior of the topographic effect to transient eletromagnetic field responses can be characterized by local anomaly for topography at receiver location, and by equivalently an extra source with strong high frequency excitation for topography at source location. Learning from the modeling results, it is emphasized that the ground wire source shall be set up at place as uniform as possible for reliable deep sounding measurements.

INTRODUCTION

One of the time domain electromagnetic survey setups for deep sounding is the so-called Long-Offset Transient Electromagnetic (LOTEM) method. The basic idea and theoretical principle of the LOTEM method have been described by Strack, 1992. A grounded wire is used to deliver current with return-to-zero square waveform down to the earth with large amplitude and long period. Receivers located at distance are used to measure the induced electric and magnetic field responses of the anomalous bodies during the source current turned off. The deep investigation can be achieved by using large enough transmitter-receiver offset.

Some field trials have been carried out for hydrocarbon exploration in Southern China. One of the difficulties encountered for geophysical exploration work in this region is due to the surface carbonate layer with rugged and complicated topography. The hulking source transmitter can be set at a fixed location far out of the survey area, while portable receivers are used as movable stations for field measurements. Therefore, the LOTEM setup seems a suitable method in view of data acquisition in mountainous area.

Conventional interpretation of TEM data is limited to one-dimensional inversion. It is a big challenge to interpret data observed at rugged area where the surface topography shows strong three-dimensional effects to the observed time series. The purpose of this paper is to examine how topography effects observed results, and hopefully to aid data interpretation.

MODEL DESIGN

A five-layer earth model with three-dimensional topography is set for numerical modeling. The topography is modeled as a V-shaped three-dimensional resistive body with $\rho_a=10^8$ Ω-M. Parameters of each layer are h_i=3000,100,100,1800,∞ in meter and ρ_i=50,500,10,50,500 Ω-M (i=1,2,3,4,5).

Model • shown in Fig.1 simulates valley topography at source location, the grounded wire electric source is 200 meters in length and along the valley in *x* direction. The simulated valley is 200 meters in depth, 100 meter wide at bottom and 400 meter wide at top, and extended 4300 meters in *x* direction. There are 21 receivers, which do not show up in Fig.1, lined up along *y*-axis in 200 meter equal spacing, with offset from 3000 to 7000 meters.

Model • shown in Fig.2 simulates valley topography at receiver locations. All parameters of the simulated valley are the same as in Fig.1, but the center of the valley is located at *y*=5000 meter now. More receivers are placed at the slope of the valley, the number of receivers is 29 for this model setup covering the same offset range as in model • . Notice that the grounded wire source is located at *y*=0, which can not show up in this diagram.

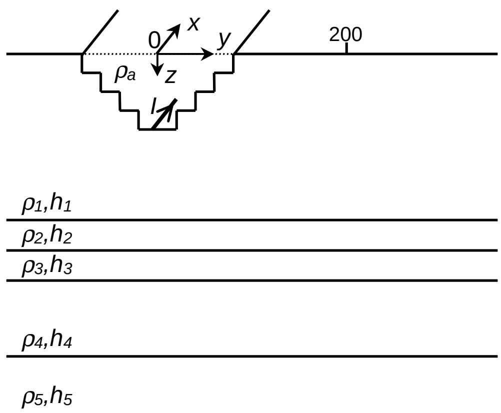

Fig.1. Model • -simulated valley topography at source location.

MODELING RESULTS

The algorithm used for three-dimensional time domain forward modeling is the volume integral equation solution in frequency domain and then transformed to time domain responses by digital

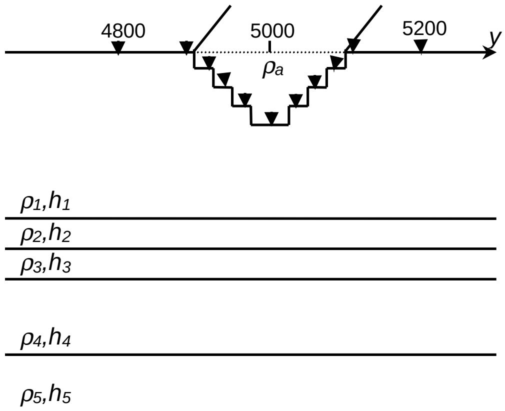

Fig.2. Model • -simulated valley topography at receiver locations.

filtering, as described by Newman et al., 1986. The response of layered earth model only (ρ_a=ρ_1) are taken as the normal response, and the anomalous response due to the three-dimensional body is the difference of the total field to the normal response. To express the relative anomaly due to the topography, the ratio of anomalous field to normal response in percentage is used for contouring. Model responses of horizontal electric field component E_x and the time derivative of the vertical magnetic inductance, or the so-called induced electromotive potential V_z are presented as follows.

Fig.3 is the relative anomaly of E_x and Fig.4 is the relative anomaly of V_z due to the valley shaped topography at the source location where y=0. Measurements are taken for offset of 3000~7000m, and for time of 0.001~10s. Notice that the time axis labels are the transformation of –log10(t) so that the upper end of the axis corresponding to early time (0.001s) and the lower end of the axis corresponding to the late time (10s) response. The contour interval is 1% for both diagrams.

Observed anomaly due to the valley shaped topography at the source location show similar behavior of an anomalous body at distance. In Fig.3, significant E_x relative anomalies are observed at early time with larger amplitude and shorter persistent period for smaller offset stations. At most of the time (>0.01s), the amplitude of the relative anomaly is within 5%, and show almost no anomaly after 0.05s, but at early time (<0.01s), the E_x anomaly can be more then 100% (not show in contour). This indicates that the high frequency part of the anomaly is strong and decayed slowly with offset. The V_z relative anomaly in Fig.4 shows similar pattern as that for E_x. At early time, the largest amplitude of relative variation is about 15%, much less then that for E_x anomaly. The anomaly at time greater then 0.01s is less then 3%, which can be neglected in sense of sensitivity of the instrument. A important feature differing from E_x anomaly is that the V_z anomaly at early time almost does not decay with offset until the time is greater then 0.01s. By comparing these two diagrams, evidences indicate that the anomalous electric field is mainly due to the distortion of conductive current through earth media, while the anomalous magnetic field is mainly due to the induction effect of high frequency energy through the air. Therefore, the valley shaped topography at source location behaves like an extra source with strong high frequency excitation.

Fig.5 is the relative anomaly of E_x and Fig.6 is the relative anomaly of V_z due to the valley shaped topography at the receiver location centered at y=5000m. It is clear that both electric and magnetic field anomalies due to simulated valley at y=5000m are local effects, that is, some receiver stations show no distortion due to the simulated valley in designed offset range. The electric field anomaly almost delineates the shape of the valley with very strong distortion near the interface, and shows a little variation at late time. While the contour of magnetic anomaly shows a pair of vortexes at early time with large amplitude at the center of each vortex. There is a mirror image of magnetic anomaly shown at late time (after 1s) right at the location of simulated valley with fairly large amplitude. This pattern of anomalies indicate that the topography effect at receiver sites are due to the local distortion to the induced eddy current in the earth media by the discontinuity of the conductivity. The anomalous field caused by this current distortion decays away rapidly with distance.

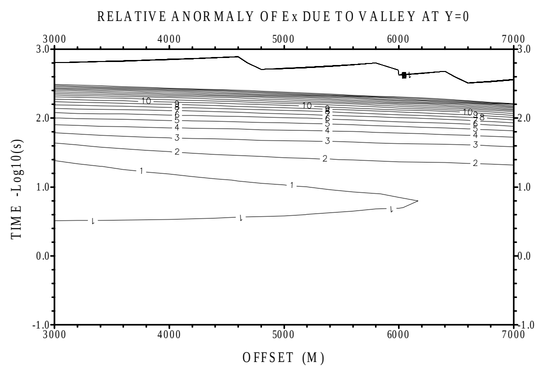

Fig.3. Contour map of relative anomaly of Ex component for simulated valley topography at source location.

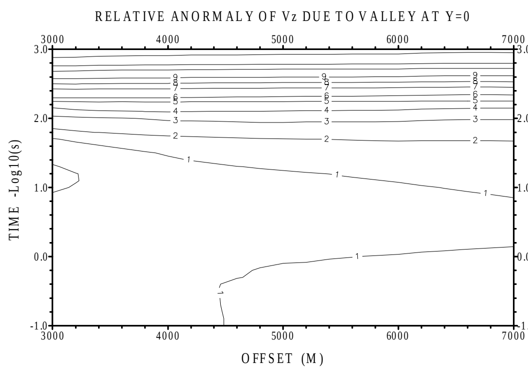

Fig.4. Contour map of relative anomaly of Vz component for simulated valley topography at source location.

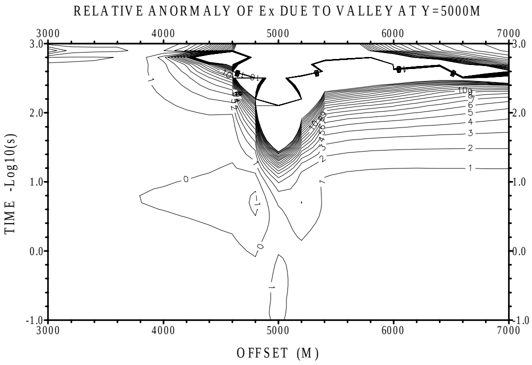

Fig.5. Contour map of relative anomaly of Ex component for simulated valley topography at receiver location.

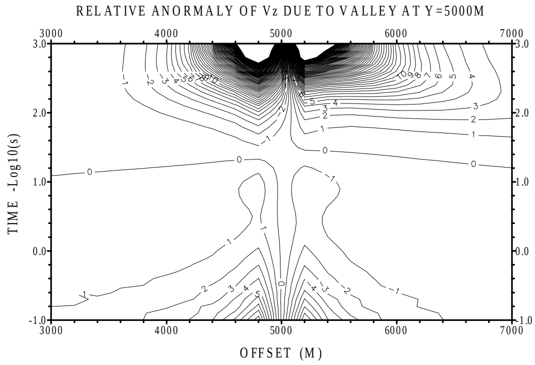

Fig.6. Contour map of relative anomaly of Vz component for simulated valley topography at receiver location.

CONCLUSION

From the above discussion, it is clear that the valley shaped topography, either at source location or at receiver location, shows strong distortion to the transient electromagnetic responses for long offset measurement using grounded wire source. The relative anomaly caused by the topography at source location can be characterized as a extra source with strong excitation at early time, while the topography at receiver site causes only local anomaly. Searching effective correcting technique for topographic effect is beyond the scope of this study. Important conclusion can be draw from this study to the topographic effect of transient electromagnetic responses, that is, the conductive anomalies including topography at or near source location indeed show significant distortion to the observed results. Setting up the source at place as uniform as possible is the key to obtain reliable field data and makes the data interpretation much easier.

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