First Shallow-Water Multi-Transient EM Survey

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Summary

We describe the acquisition, processing and interpretation of multi-transient electromagnetic (MTEM) data obtained in water 100 m deep. The data were acquired using MTEM Limited's patented technology, employing a proprietary 30-channel sea-floor receiver cable and proprietary bipole current source. The equipment was deployed along several lines to record data with very dense subsurface coverage: source-receiver offsets in the range 1,000 – 6,000 m with 200 m increments and mid-points every 100 m. Data quality was appraised and processed in real time. A special feature of the processing was removal of the air wave, which allowed the data to be inverted for subsurface resistivities using tried and tested algorithms. We present the data and step-by-step processing and inversion.

Data Acquisition

Figure 1 shows a schematic of the marine setup.

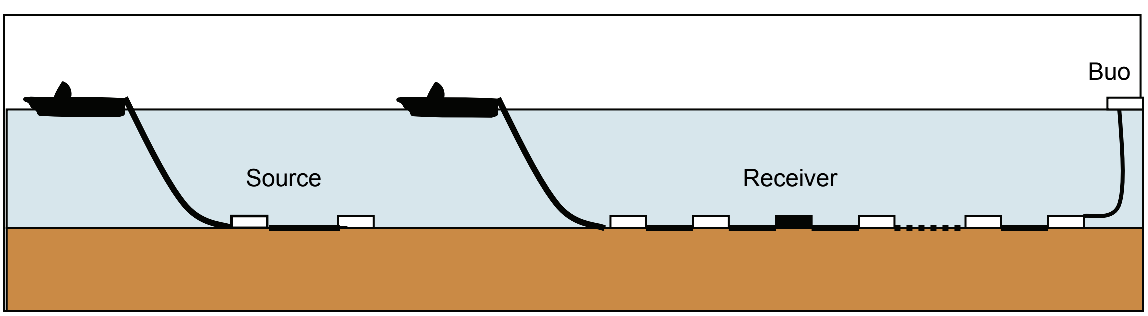

Figure 1: Showing deployment of sea-bottom receiver cable from one vessel and deployment of the bipole current source from a second vessel. Both vessels needed to hold their positions and had dynamic positioning.

The current bipole source consisted of two electrodes 200 m apart buoyed 2 m off the sea floor, and to which a PRBS was applied, switching between +700A and -700A. The source bit rate was varied for different offset ranges. The actual source current was not a perfect PRBS and was measured and then transmitted to the receiver vessel for data quality control and deconvolution. The observer on the receiver vessel controlled the source transmission.

The receiver cable consisted of 30 identical 200 m in-line electric bipoles and associated electronics modules arranged end-to-end to form a continuous 6 km line. The time-varying voltage measured by each receiver bipole was digitised and stored in the associated module and then transmitted to the receiver vessel for analysis and processing.

An acoustic transponder was attached to the receiver cable at each electrode position and the source vessel was used to ping the transponders and position the receiver electrodes to better than 1 m precision. There was also an acoustic transponder at each source electrode to enable it to be positioned to the same precision.

Data Analysis, QC and Processing

The on-board setup for data analysis and quality control consisted of two PCs: the *MTEM Observer* for the observer to control the data acquisition, set parameters, and observe data quality; and the *MTEM QC*, for the field geophysicist to analyse the data and perform preliminary processing, including deconvolution. Figures 2 and 3 show typical displays from the two computers.

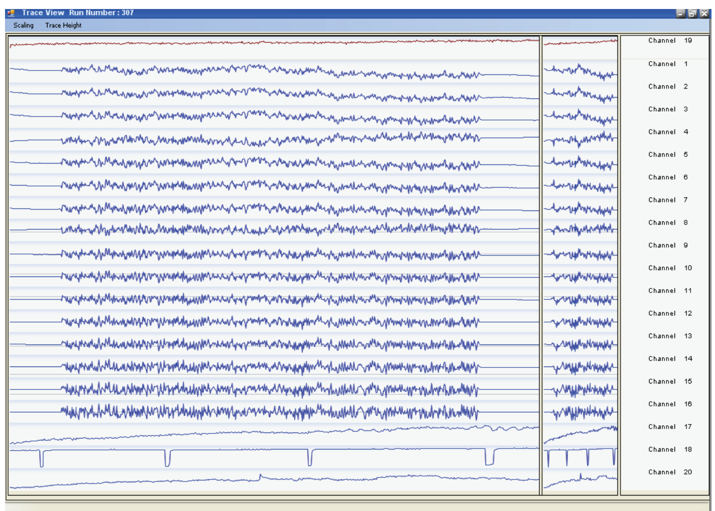

Figure 2: Screen grab from *MTEM Observer*, showing a source record with offset increasing from bottom to top. The response to the PRBS can clearly be seen on all channels. The low-frequency noise level appears to increase from bottom to top, but in reality it is the signal level that is decreasing.

The incoming data were read onto a disk on the *MTEM Observer* and read off that disk onto a disk on the *MTEM QC*. We needed to know that the data quality wass adequate for subsequent inversion. Typically we require that the peak of the earth impulse response is about 30 dB larger than the background noise level. Figure 3 shows one of the steps in this quality control procedure. If the signal-to-noise ratio, or the resolution, is not adequate, the data acquisition parameters need to changed. These parameters include the source bit rate, order of the PRBS, number of cycles, and receiver sampling rate. Data with the correct parameters were acquired before moving to the next position.

A problem with marine EM data is the air wave, which needs to be removed before the data can be inverted. Figure 4 shows a display of the result of removing the air wave. The method for removing the air wave is described in Ziolkowski and Wright (2007).

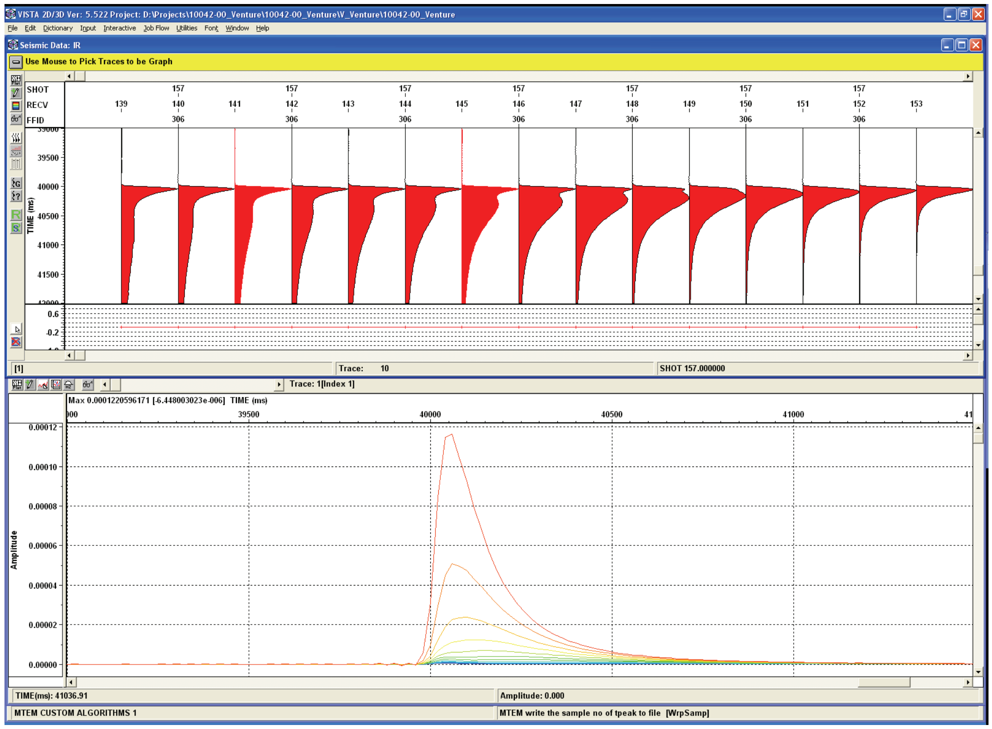

Figure 3: Screen grab from *MTEM QC*, showing recovered impulse responses. In the top display offset is increasing from right to left and the data are normalised to the maximum value. The bottom display shows the same data un-normalised.

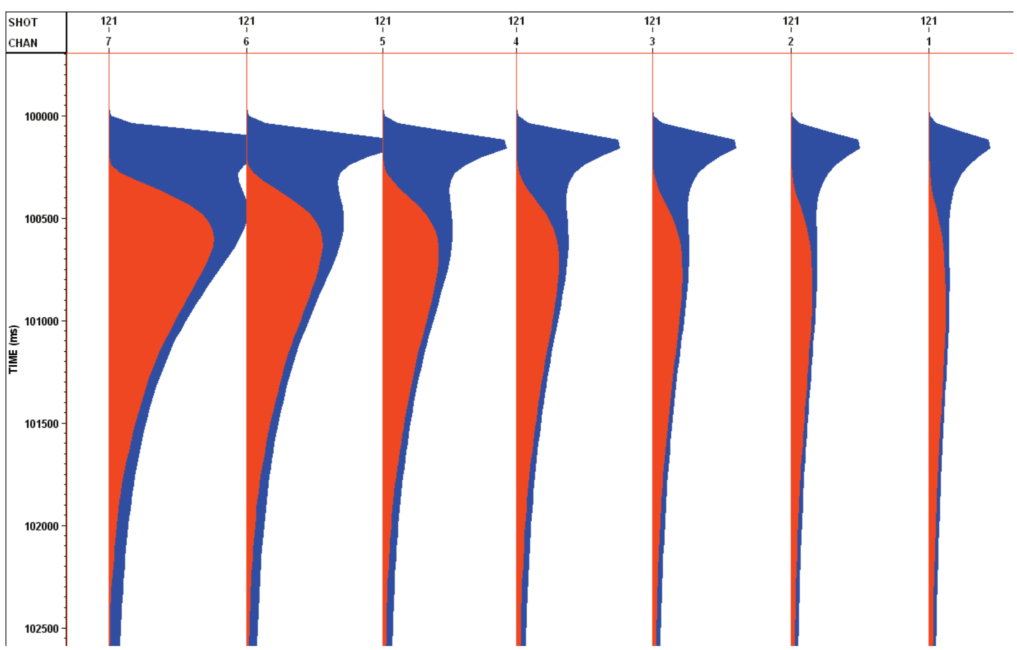

Figure 4 Impulse responses for offsets 2800 to 4000 metres: total response in blue; air wave removed in red.

Results

The data were arranged in common mid-point (CMP) gathers and, starting with a simple half-space, a one-dimensional model was found by Occam inversion (Constable et al., 1987) for each gather. The model results for each CMP position were displayed side-by-side. Figure 5 shows preliminary unconstrained inversion results from one MTEM line, with the corresponding seismic data below. The resistive target to the left of the well position roughly corresponds to the bracketed bright spot on the seismic data.

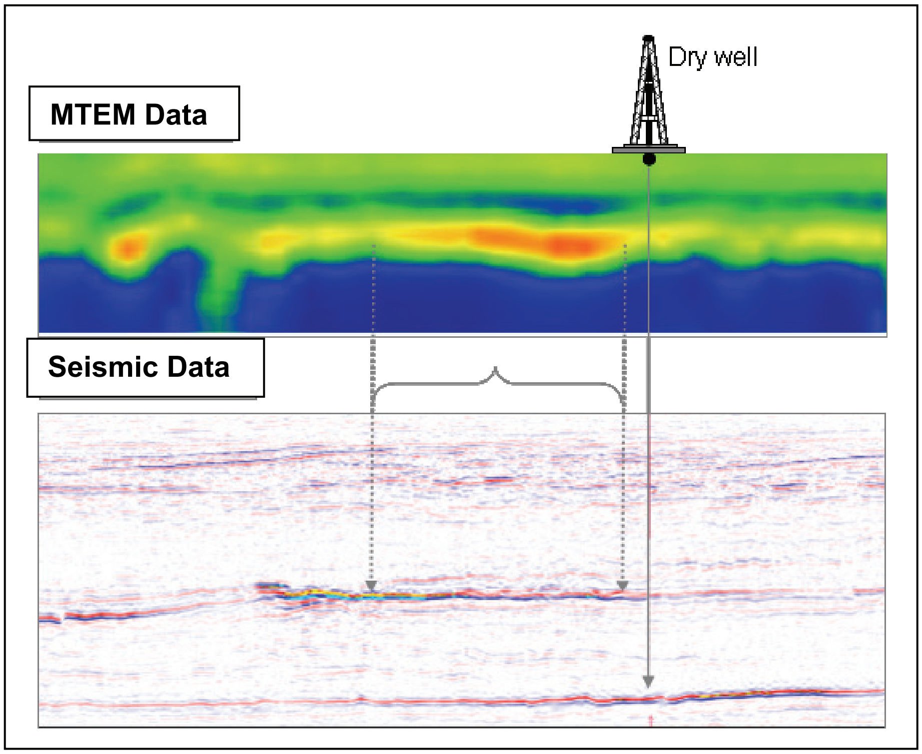

Figure 5: Unconstrained inversion of MTEM data and corresponding seismic data on the same 22 km line. Blue is least resistive, and red is most resistive.

Conclusions

We have obtained excellent marine multi-transient EM data in shallow water in the the North Sea. The air wave has been successfully removed and the data have been readily inverted using an unconstrained Occam inversion to reveal a promising resistive target that correlates with a seismic bright spot.

Acknowledgements

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References

Constable, S. C., Parker, R. L., and Constable, C. G. (1987) Occam's Inversion: A practical algorithm for generating smooth models from electromagnetic sounding data. *Geophysics*. 52:289-300.

Ziolkowski,A.M., Hobbs,B.A. & Wright,D.A., 2007. Multi-Transient Electromagnetic Demonstration Survey in France, Geophysics, 72, 197-209.

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