Introduction
The most northerly of the Brazilian equatorial margin basins where the deep water is virtually unexplored, with only two wells drilled in the Amazon Cone.

The 11th License Round, focussed on the potentially large reserves in distal, Late Cretaceous/Palaeogene deep water turbidite plays encouraged by successful wells in French Guiana and in the offset, conjugate margin in Africa (Sierra Leone- Liberia), Venus, Mercury and Jupiter Turonian and Campanian slope channel fan complexes, and Zaedyus Upper Cretaceous play in French Guiana. The assumed source rock is Cenomanian-Turonian (C-T) and latest Albian. This play is assumed to extend into the deep water FdA Basin.

In 2012 Spectrum acquired 21,369 km of 2D seismic, gravity and magnetics data. In 2013 EMGS conducted approximately 4,500 km² of 3D Controlled Source Electro Magnetic (CSEM) data acquisition.

Lithology or hydrocarbon response?
Series of resistive CSEM anomalies identified. By choosing an average resistivity window that encompasses the expected burial depths of the Lower Tertiary - Upper Cretaceous channel systems, some EM anomalies resembled channel geometries - mostly elongate with branching geometries appearing to infill incised channel systems mapped at a Late Cretaceous/Palaeogene unconformity level. More detailed analysis revealed that some of the channels were associated with high resistivity, while most channels were not, and that some anomalies were not associated with the channels. These observations led to a comprehensive quantitative...
integration of the unconstrained CSEM anomalies with all available seismic data types, in order to better define if the resistive events were more likely to be due to the presence of hydrocarbons rather than to the remobilization and deposition of Tertiary shelfal carbonates.

This study aimed to identify the lithology of the canyon fill and characterize the source of the anomalies using seismic attributes, facies distribution, stacking velocities and angle stacks. High resistivity anomalies were mapped with respect to the three main play types identified in a previous seismic study: Palaeocene/Cretaceous canyons, High acoustic impedance slump facies, Cretaceous slump/ponded fan sequences.

**Seismic Attribute Analysis**

Qualitative integration was carried out using map, vertical and three dimensional displays with identified CSEM anomalies superimposed on play type distribution and all available seismic data types. Quantitative integration was accomplished by cross-plotting different seismic attributes extracted over different windows against CSEM vertical and horizontal resistivity values as well as vertical/horizontal values (anisotropy ratio described in Chakraborty S. et. al, 2013). Windowed attribute analysis was used to overcome the limitations in CSEM anomaly vertical resolution.

**Channel Confined Anomalies**

Most of the CSEM anomalies were associated with channel infill. Seismic facies and horizon correlation supported a Cretaceous age for the base of the channel. Co-rendering results from seismic vertical displays supported by cross-plot analysis with seismic attributes, indicated the resistive anomalies were more likely to be generated by hydrocarbon saturated reservoirs than by carbonate-dominated lithology.

**Analysis Windows**

<table>
<thead>
<tr>
<th>Attribute types plotted against CSEM Vertical Resistivity</th>
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<tbody>
<tr>
<td>Stacking Velocities and Gradient</td>
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<tr>
<td>Far-Near*Far</td>
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<tr>
<td>Frequency</td>
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<td>Envelope</td>
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<table>
<thead>
<tr>
<th>Attribute values</th>
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<tr>
<td>Absolute Max Value</td>
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<td>Mean Value</td>
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<td>RMS</td>
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**Lower cut-off Deeper Anomalies**

**Windows used**

- Mid to Base Anomaly
- 100 m+Base Channel

**Attribute map and crossplot**

**Analysis Windows**

spectrumgeo.com/techpapers
CSEM anomalies are observed in deep water sediments with varying strength. Lowering the cut-off in three dimensional displays as well as analysing the anomalies obtained from the anisotropy ratio volume, highlighted a series of potential, additional anomalies associated with the slump/ponded fan sequence deeper play. The presence of these deeper anomalies was confirmed and the strength increased by new 3D inversions.

**New Inversion Considerations**

Two major contributing factors for stronger, deep anomalies in the new inversions were receiver subsets and reprocessing data to increase useable offset for the base frequency. The full receiver grid was divided into regions. A subset receiver grid where the shelf data is excluded enhances model updates in the deep water sediments – a shift in focus from mostly basement updates to resolving subtle deep water features. In addition, the data was reprocessed to increase the offset for the base frequency (0.156Hz) to boost sensitivity to the deeper slump/ponded fan sequence. With longer offsets available, the weight...
of the data points sensitive to the deeper parts of the model was increased and the combination of these factors increased the strength of the deep anomalies.

Conclusions
The integration of modern seismic, gravity, magnetics and CSEM data provides a powerful exploration tool for de-risking exploration leads independently identified in frontier basins. With potentially large leads and large areas of open acreage, Foz do Amazonas provides an exciting frontier exploration opportunity.

Acknowledgements
We would like to thank EMGS for their contribution and permission to publish this material.

References
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