Marking the edge of reservoir with new approach of processing & Inversion algorithm – A case study from offshore Krishna-Godavari Basin, East coast of India

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Abstract

Two 2D CSEM lines were acquired and processed in offshore Krishna-Godavari basin in 2006, a few years after the commercialization of marine CSEM acquisition. Since that time, the technology has evolved and matured significantly to become accepted by E&P companies as a robust prospect de-risking tool. In 2006 the processed deliverables to the client were limited to charts of attribute analysis. In this paper, we present the additional information that has been extracted from this legacy survey following recent reprocessing with the current processing and inversion algorithms that have been able to image the lateral extend of the reservoir, within the limitation of 2D data.

From the unconstrained inversion results derived without a prior information, the CSEM data shows an anomaly that corresponds to a discovery well, and no response at another well that was dry or non-commercial discovery.

Introduction

An innovative approach has been adopted to apply the latest processing and inversion algorithms to image the lateral extent of a reservoir body from legacy 2D marine CSEM data acquired in 2006, and to integrate the results with seismic and well log data. CSEM measures the resistivity contrast in the subsurface, and is very effective in identifying lateral variations. By combining CSEM with seismic data it is possible to better understand the lateral extent of prospective reservoirs and use this information to validate a prospect portfolio for future exploration.

Two 2D CSEM lines with multi-frequency electric and magnetic field CSEM data were recorded in the shallow water study area.

In this paper, we applied new processing and 2.5D inversion algorithms to the existing data to extract additional information like lateral extent of the reservoir along the 2D lines and to correlate it with available interpreted seismic and well data.

Geological setting of offshore KG basin

The Krishna-Godavari Basin is known for having India's largest natural gas reserves. The KG basin extends more than 50,000 sq.km in the Krishna and Godavari river basins in both onshore and offshore (Figure 1). The basin is situated along the shoulder of a rifted passive continental margin which developed during the separation of India from Antarctica in the Late Jurassic (R. Bastia 2006).

The basin’s characteristic feature is its en-echelon horst and graben system which is filled with a thick pile of sediments of Permian-to-Recent age and emerging as one of India’s most promising petroliferous areas. Commercial accumulation of hydrocarbons occurs in sediments from the Permian to as young as the Pliocene (S K Gupta 2006).

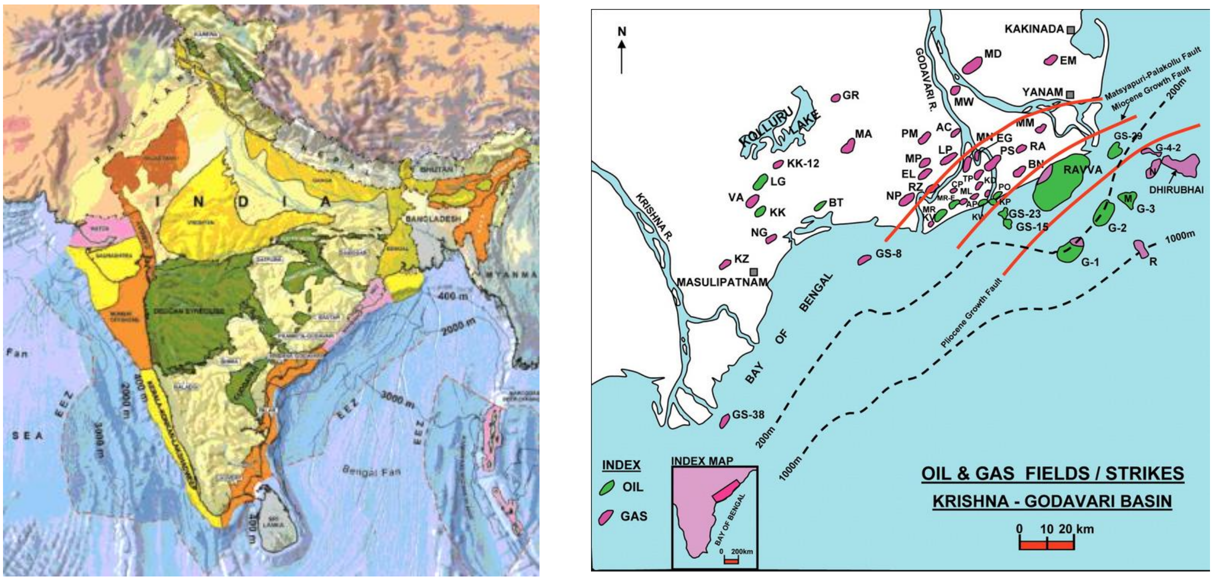

Figure 1: Location Map of Krishna-Godavari basin

Methodology

The data has been re-processed taking advantage of 2.5D Inversion. 2.5D inversion without any constraints from seismic or well-log data was performed in order to image the resistivity distribution and reveal resistive anomalies in the subsurface, if any.

Some uncertainties have to be considered in the inversion results, due to:

- Poor receiver timing (and thus limited phase data quality) as the data were acquired with early generation CSEM instrumentation.
- Limited Vertical Resolution of the CSEM method

Workflow Steps:

The processing workflow below was applied in an iterative manner to reprocess the 2D lines.

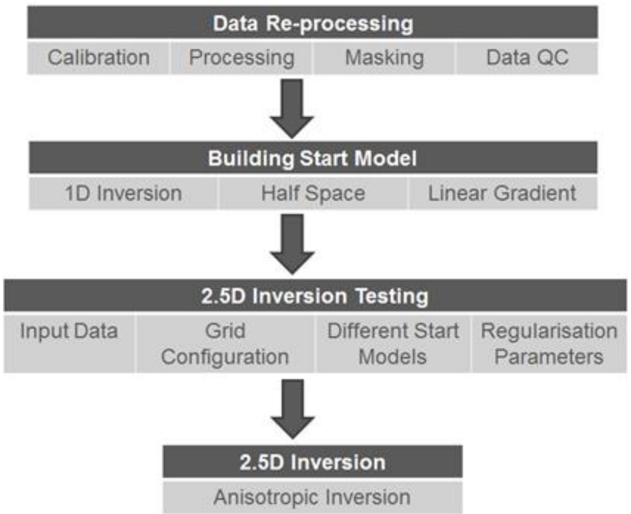

Figure 2: Processing & 2.5D Inversion Workflow

2.5D unconstrained CSEM Inversion Results (2013)

In 2.5D inversion, it is assumed that the receiver and source positions are located along a line, and that the resistivity (R) varies little in the direction perpendicular to the source towline. Defining a right-handed coordinate system with X-axis pointing along the towline, Y-axis pointing perpendicular to the towline and the Z-axis pointing down, the 2D approximation implies that R(X,Y,Z) ≈ R(X,Z) in the vicinity of the towline, and the earth is thus described by a 2D model. Since the electromagnetic field from a dipole CSEM source varies in all 3 dimensions, the modeling of 3D fields in a 2D model is termed 2.5D.

In general, a CSEM inversion algorithm attempts to find a resistivity distribution R(r) which produces synthetic data $d^{syn}(R(r))$ matching the observed data d^{obs}. The misfit between observed and synthetic data for a given model is measured by defining a data error functional ED (R(r)). A low value from this function indicates that the misfit between observed and synthetic data is small (ie. a good fit). (Kristian R. Hansen, 2009)

In 2006 EMGS acquired 2D CSEM data along two receiver lines (Figure 3), with all receivers deployed prior to towing the CSEM-source.

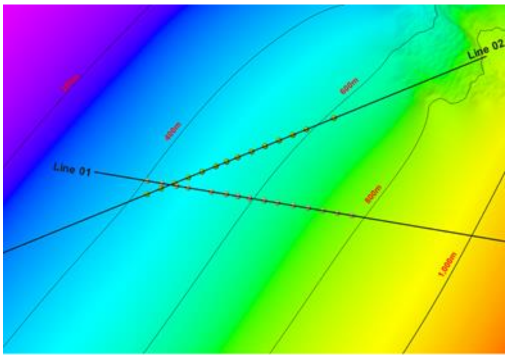

Figure 3: Survey layout with bathymetry map for (2006) CSEM lines offshore Krishna Godavari basin, East Coast of India

The legacy data have been inverted in accordance with the 2.5D inversion workflow described above. From the preliminary 1D inversion an average resistivity value has been estimated to create a half space start model for both of the lines. 2.5D anisotropic inversions were run using this start model giving the results shown in Figure 4 & 5.

To check the robustness of the inversion results, a start model with a linear depth gradient of resistivity has also been used to perform 2.5D anisotropic inversion and results were the same as for the half space start model.

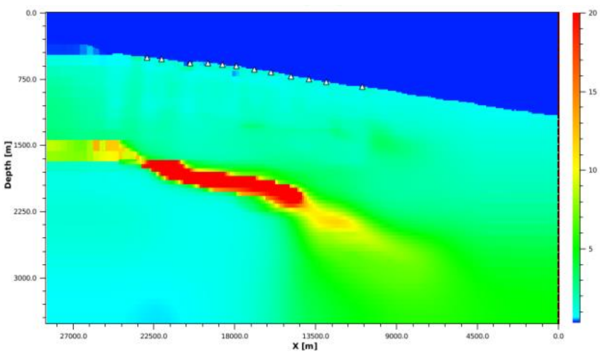

Figure4: 2.5D unconstrained inversion result of line 01 in offshore KG basin, East coast of India

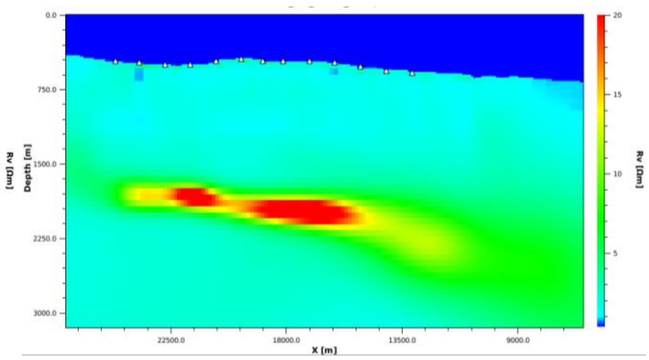

Figure 5: 2.5D unconstrained inversion result of line 02 in offshore KG basin, East coast of India

Findings:

Line 01:

On Line 01, a resistor is resolved at a depth between approximately 1,950m to 2,050m below MSL. After overlaying seismic to the vertical resistivity model, the resistive response correlates with a channel identified in the seismic. This has been further validated by two discovery wells drilled. The resistivity log from the well also exhibits a good match with the CSEM response.

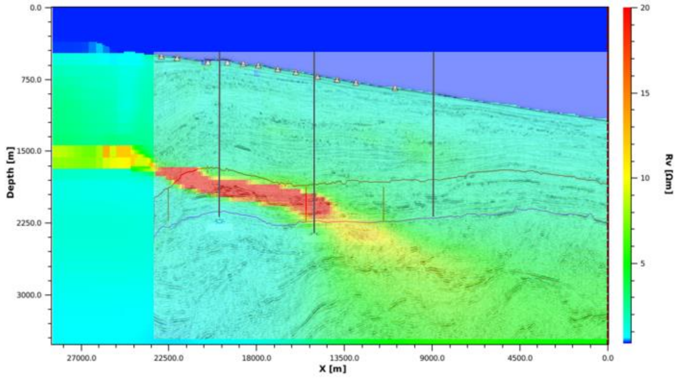

Figure 6: 2.5D unconstrained inversion result overlain with seismic for line 01 in offshore KG basin, India

Apart from the good match of CSEM response on line01 with seismic and well log data, it also identified the lateral extent of the reservoir along the 2D profile. Solely on the basis of the seismic data it is difficult to identify the extent of the reservoir with high hydrocarbon saturation as seismic is not sensitive to saturation of hydrocarbon whereas CSEM is directly linked to hydrocarbon saturation. So integration of CSEM data with seismic can give a more complete picture of the reservoir.

An increase in resistivity in well data was encountered somewhat deeper than predicted by the CSEM; however, this difference is not much and could be there due uncertainties in 2D CSEM data.

Towards the end of line 01(south east), one more well was drilled and found to be dry. Looking at the CSEM inversion result, no resistive anomaly is observed in that part, which is in agreement with the absence of hydrocarbon in that area.

Line 02:

On Line 02, two resistors were identified at a depth around 1950m & 2150m below msl. Both resistors have good correlation with high seismic amplitudes which correspond to hydrocarbon discoveries.

On this line there are two different fields adjacent to each other with a bit of vertical separation. The CSEM inversion result (Figure7) also indicates two different resistors associated with these fields and their lateral extent along the 2D profile.

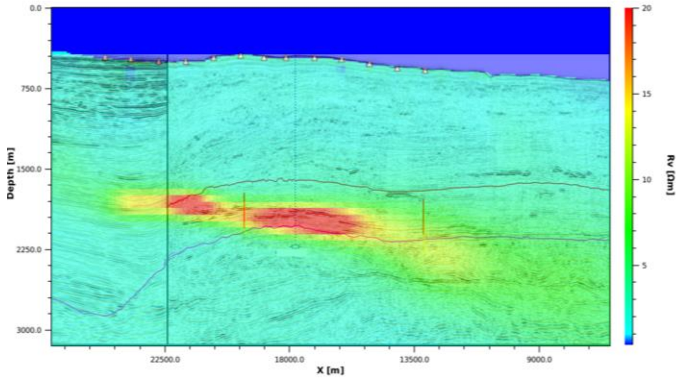

Figure 7: 2.5D unconstrained inversion result overlain with seismic for Line 02 in offshore KG basin, India

Conclusions

Reprocessing of 2D CSEM data in Krishna-Godavari basin acquired in 2006 produced inversion images, which are much more useful for interpretation in comparison to CSEM data attribute maps. Unconstrained 2.5D inversion was performed and results were analysed in the light of well-logs. CSEM inversion images were also overlain with seismic and they were correlating well. With the help of CSEM, the lateral extent of reservoir was identified, which can be challenging with seismic data alone. The CSEM response for Line01 & Line02 matches with the drilled discovery wells and also the dry well on Line01 corresponds to no CSEM response.

From this reprocessing, it is clear that state-of-the-art CSEM processing tools can produce good quality inversion images of resistivity that may help oil companies find hydrocarbon saturated zones in combination with seismic data.

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