P - 281

Simultaneous Angle Dependant Inversion (SADI) for Reservoir Characterization & Field Development.

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Summary

This work presents the results of simultaneous angle dependant seismic inversion (SADI) applied to identify and delineate a gas charged reservoir in the study area, situated at in the offshore area of the east coast of India. This methodology, along with the interpretation of 3D seismic & other attribute analysis, substantially reduced the risk associated with development well locations.

The work flow for this analysis started with a detailed well log interpretation based on petrophysical modeling and seismic processing that provided partial angle stacks of the CDP gathers processed with true amplitude and pre-stack time migration. Attribute volumes comprises of P-impedance (PI), S-Impedance (SI), Vp/Vs, Lambda-Rho, Mu-Rho, and Poisson´s Ratio were calculated using Jason's simultaneous inversion process. This process is based on the information of the variation of the reflectivity with the angle of incidence included in the partial angle stacks and Knott & Zoeppritz formulations. The Rock Trace Index, (RTI), a measure of perpendicular separation of PI & PS cross plot points from the line in crossplot which separates the hydrocarbon bearing sands from the brine sands and shale, volume was computed from P-impedance, S-Impedance using Jason's software.*

The above mentioned attributes show a distinctive behavior in terms of the lithology and fluid content that allows a superior definition of reservoir and fluids through an integrated volume analysis methodology. In the study area, the producer gas charged geobody was captured, delineated and subsequently validated.

There is a very good agreement between the well results and the simultaneous inversion. New wells drilled based on this study matched with the predicted lithology and gas content.

Introduction

The study area is oil & gas charged reservoir in the recently discovered field in the deep water are of east coast of India. Two wells, discovery well (W1) & appraisal well (W2) were drilled in this area. Well W1, drilled on the basis of 3D seismic, is structurally (time) higher (20msec) than the well W2, however, the well W2 is 100m shallower than well W1 in depth.

The zone of interest is capped by an unconformity and composed of highly gas-saturated sands with thin, inter-bedded shale units as well as an underlying oil-saturated column. The depositional history of the field is complex and includes continental, lacustrine and marine deposits.

The reservoir is composed of fluvial braided channel deposits, which makes it highly heterogeneous and difficult to image.

The objective of this study was to delineate and characterize the reservoirs in the area based on the interpretation of results derived from Simultaneous Angle Dependant Inversion (SADI) and to identify development well locations.

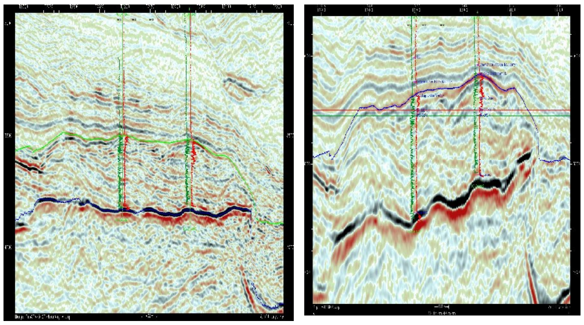

Fig.1. (a) Time section (b) Depth Section along two wells. Well W1 is structurally higher (20msec Two way time) than well W2 but deeper by 100m in depth.

Theory

The inversion process converts seismic data from interface properties to layer properties. The used inversion engine utilizes sparse spike inversion, a linear inversion technique that minimizes the misfit between the observed seismic data and the synthetics generated through convolution model subject to the constraint that the sparseness of the inverted reflectivity series is maximum. In other words, one can say that in view of band limited nature of of the seismic data, there can be infinitely large number of reflectivity sequences that can explain the observation. But the strategy adopted in CSSI is based on the philosophy that the nature can be explained with less complexity wherever possible.

Misfit or Error = Squared difference between observed and synthetic + a factor * (sum of absolute values of the reflectivity)

This is calculated for each trace in the inversion time window. The second term in the above equation acts as a constraint. The factor is optimized through experimentations. The modeled reflectivity is then used to predict acoustic impedance, Vp/Vs and density using the Aki Richards reflectivity approximation.

Data Conditioning and Processing

1. PSTM processing was carried on 3D seismic data acquired during 2002 with bin size of 12.5m X 25m and partial angle stacks of near (5-20^o), medium (17-32^o) and far angles (30-45^o) were obtained. (Figure 2)

2. Log editing, calibration and modeling of complete suite of logs, Vp, Vs and Rhob (Xu, S. & White, R., 1995) are carried in two wells. Fluid substitution analysis (Gassmann, F., 1951) was performed to evaluate differences in shear impedance and acoustic impedance (normal incidence) in reservoir sands with different fluid content. Log modeling results are aimed at predicting reservoir lithology and fluids and to assure an accurate wavelet extraction process.

3.Three partial angle stacks, the extracted wavelets corresponding to each one of the angle stacks, the constraints and a well log based low frequency model were used as input data. Based on the application of Zoeppritz or Aki & Richards (1980) equations, P-impedance, S-impedance and Density cubes are simultaneously obtained through SADI. Attribute volumes of Vp/Vs, Poisson's Ratio, Lambda-Rho y Mu-Rho were also computed (Figure 2).

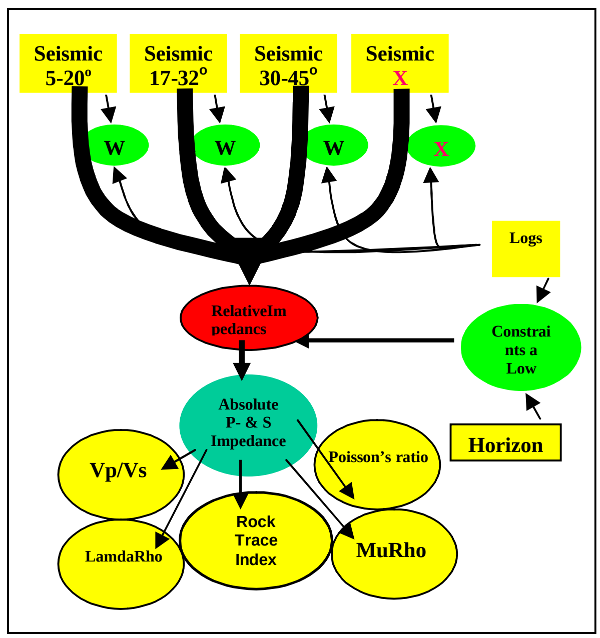

Figure-2: Generalized Work Flow for Simultaneous Angle Dependat Inversion (SADI) .The inputs are angle stacks, derived wavelet corresponding to each angle stacks, Constrained log derived low frequency model. The output attributes : P-Impedance, S-Impedances,Vp/Vs, Poission's ratio, Lamda-Rho & MuRho.

Lithology and Fluid Characterization

P wave velocity is affected by fluid content in the reservoir and so do P impedance, Poisson's Ratio, Vp/Vs and

Lambda Rho. The information related to shear wave velocity obtained form SADI substantially increased the ability to identify fluids and lithology.

Multiwell and multivariable cross-plots, derived from the well logs and SADI results, allowed characterization of fluids and lithology. P-Impedance (PI) and S-Impedance (SI) were cross-plotted and the RTI baseline defining the functional relationships of gas sands were interpreted (Figure 3a and 3b).

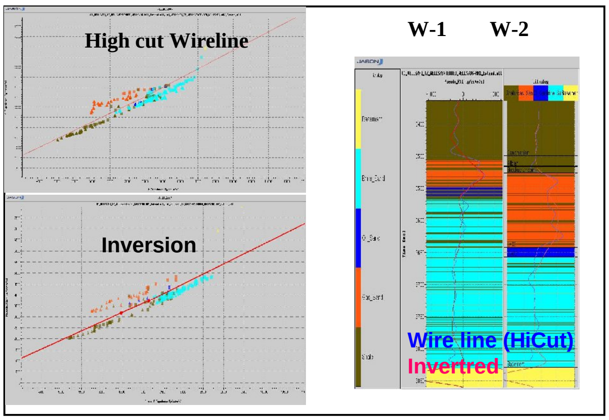

Figure 3a: Cross plot PI &SI using high cut wire line log data and Inversion data .
Figure 3b: RTI log calculated from wire line logs with high cut (Blue Curve) and RTI log computed from SADI (Red Curve) for well-W1 and Well-W2.

In this study, a combination of P-Impedance (PI) & S-Impedance (SI) ,Poisson's Ratio,& Vp/Vs and Rock Trace Index(RTI)*, were studied. The Vp/Vs and Poisson's Ratio demonstrated to be good fluid indicators (Figures 4a and 4b). RTI (Figure 5) clearly shows the sand bodies facilitating the interpretation of depositional geometries and sand content of the reservoirs. The match and tie between seismic and wells is very precise. The values of Vp/Vs and Poisson's ratio derived from well data are directly and quantitatively compared to the results of SADI. Since the results of the inversion are not derived from well data, the well to seismic match indicates the quality of SADI.

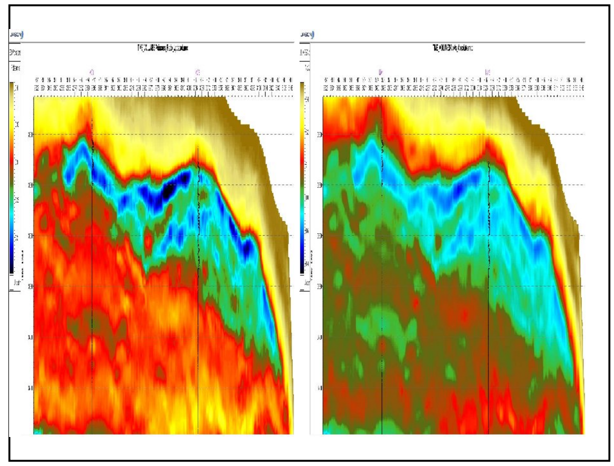

Figure-4 (a) Poisson's Ratio (b) Vp/Vs clearly outline the reservoir geometry.

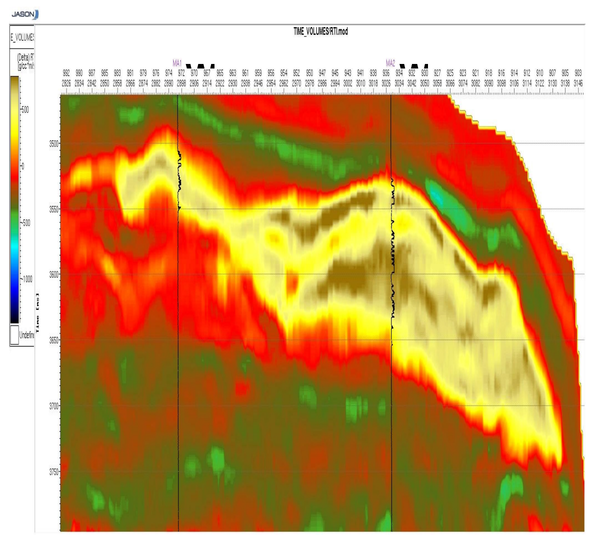

Figure-5 Rock Trace Index(RTI) identifying fluids and lithology

Geobody Capture

Functional relationships from well data were applied to the SADI output cubes to isolate the cells satisfying the conditions of pay zones. Geobodies were subsequently generated by applying minimum size and connectivity criteria. (Figure 6). Once the geobodies of interest were selected, structural top and base and thickness maps were generated. The volume of each geobody was then obtained by adding those cells while honoring pay functional relationships and face connectivity criteria.

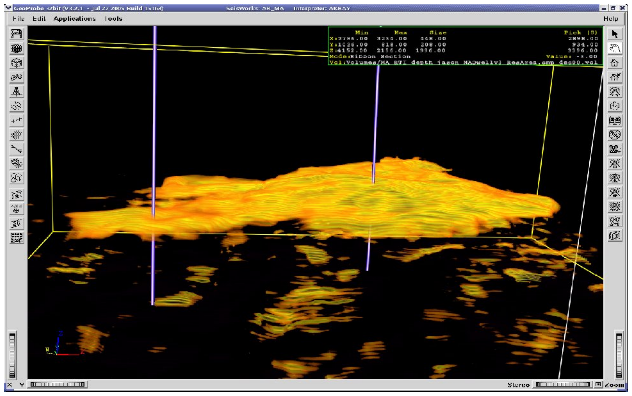

Figure-6 Geobody Captured using RTI cutoff delineates the reservoir extent

Blind Well Testing

On the basis of the simultaneous angle dependant Inversion and analysis of RTI, Vp/Vs and Poission’s ratio two development wells were planned and drilled. The lithology and fluid content of these drilled wells is agreement with the prediction made on the basis of the study(Fig 7)

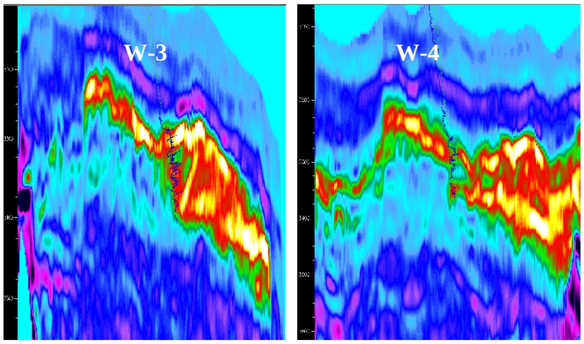

Figure-7: Lithology predicted for Well-3 & 4 agrees with drilled data

Conclusion

- The higher resolution of the layer model derived from SADI provides a better well to seismic tie to support reservoir characterization.
- Seismic resolution was inadequate for development well planning .However , SADI helps in planning of development wells.
- The use of variables related to shear wave velocity derived from SADI substantially increases the ability to define fluid and lithology.
- The results of the well proposed and drilled based on this study are in agreement with the lithology and gas content predicted from the results of the SADI conducted in this study.

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