Interpretation of Subtle Channel-Fan system in Dharvi Dungar Formation of Barmer Basin, India using Calibrated Spectral Decomposition Data

Venkateswara Rao Kola; Nepal Singh; Ashesh Desai; Soman Chacko; Pinakadhar Mohapatra*
Cairn India Limited, India
venkateswararao.kola@cairnindia.com

Keywords

Spectral decomposition, RGB blending, tuning cube, Well calibration

Summary

Dharvi Dungar (DD) Formation is of Eocene age, deposited during the rifting phase of the Barmer Basin. Sand development in the Formation is generally poor. Dharvi Dungar reservoirs are turbiditic deposits, commonly only 3–4 m thick, seldom reaching more than 10 m in thickness, with high porosities but low permeability. Given the thickness limitation, we applied Spectral Decomposition to the 3D seismic data covering the study area to interpret the morphology of DD turbidite fan units. Results in the form of seismic cubes of different frequencies clearly demonstrate the thickness variability of sands within the turbiditic channel and fan system. RGB color blending with low-mid-high frequencies was used to depict various depositional elements of the turbidite bodies. Well calibration was done by comparing seismic spectral tuning effects in the Spectral decomposition volumes with equivalent effects in data obtained from spectral decomposition of 1-D well synthetics; this step validated and increased the reliability of results.

Introduction

The Barmer Basin in Rajasthan where Cairn operates the RJ-ON-90/1 Block is an intra-cratonic rift basin and a northward extension of the Kutch or Cambay basins. It trends NNW-SSE and forms a well-defined graben between the Barmer high on the west and the Indian shield on the eastern side. The thickness of sediments within the Barmer Basin, based on well data is in excess of 6000 m in vicinity of the Raageshwari field in the southern part of the Barmer basin (sediments in the basin increase in thickness to the south). The basin contains Jurassic to Recent sediments overlying Proterozoic basement.

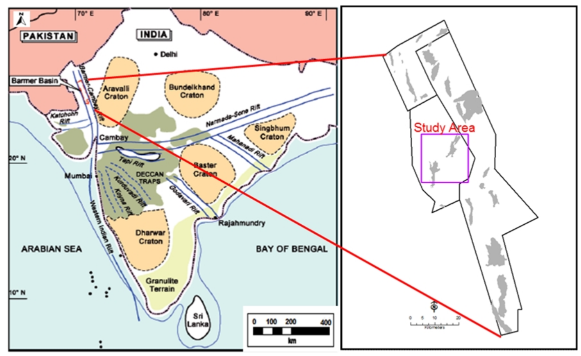

Figure-1: Location map of study area

Geology of Dharvi Dungar Formation

This paper concerns a study of the Dharvi Dungar Formation which contains syn-rift Eocene age strata. Dharvi Dungar is generally sand poor and is represented by several depositional cycles comprising lacustrine shale, fluvial sandstone, and swamp lignites. The syn-rift Dharvi Dungar and Thumbli Formations have mostly tested commercial oil only in the Central Basin High of the Barmer Basin, in the Raageshwari and Guda fields. Both formations are sand poor and where proven productive, with reservoirs characterized by fine grained, low-sinuosity channels and crevasse splays. These reservoirs seldom reach more than 10 m (33 ft) in thickness and are commonly only 3–4 m (10–13ft) thick, with high porosities but low permeability.

Dharvi Dungar Formation is considered as a regional seal for the Barmer Hill and Fatehgarh reservoirs in the Barmer Basin. Initially considered as having been deposited during a major transgressive cycle, subsequent integrated studies with seismic and well indicate presence of at least three regressive cycles bringing in coarser clastics in the Basin during Late Paleocene-Early Eocene. Due to limited thickness, individual reservoir units are difficult to map in conventional seismic data. And certain advanced seismic attributes have been used successfully to decipher sand fairways and reservoir geometries in Dharvi Dungar Formation.

Seismic Attribute analysis

A bright, anomalous seismic RMS attribute anomaly within the DD Formation was tested by well-A which flowed oil, and resulted in a new play discovery. Lateral distribution of the thin oil bearing DD sand, which lies within a thick argillaceous unit, is interpreted to be limited as it is not present in nearby wells.

Attempts were made using various seismic attributes calibrated to wells to delineate the extent and morphology of the sand distribution. The RMS amplitude attribute indicated anomalies associated with sand only, but the Sweetness attribute showed both channel impressions with bright amplitude anomaly. The latter is because Sweetness attribute measures a combination of amplitude and instantaneous frequency. The frequency component responds to variation in bed thickness. This analysis suggests that a frequency related technique might aid delineation of thin DD sands.

Spectral Decomposition

Although oil was discovered in DD sands, we found it difficult to reconcile the distribution of associated amplitude anomalies with expected turbidite depositional patterns. Based on results of Sweetness seismic attribute analysis, Spectral decomposition was performed on seismic data over the discovery area. Spectral Decomposition is a technique to delineate thin stratigraphic units that are below seismic resolution. It has been used in conjunction with visualization technologies to effectively delineate channel fan distribution and morphology.

There are several types of spectral decomposition algorithms available in the industry, each having unique advantages and disadvantages. For this study we applied the Continuous Wavelet Transform (CWT) method to transform conventional stack seismic amplitude data into frequency cubes ranging from 12Hz to 48 Hz in intervals of 4 Hz.

Results show that 12 Hz data tunes the reservoir sand and clearly defines channel fan morphology in the study area of the discovery. The well is also seen in this frequency data to have penetrated a DD fan facies. With frequencies increasing from 12 to 20 Hz, the channels are seen to fade, while finer scale internal fan architecture becomes visible. Tuned responses in 24 Hz to 48 Hz clearly delineate the internal fan structure, indicating turbiditic deposition with feeder channels towards the south of the well-A area.

We used RGB color blending to composite three frequency components, with red color representing the low frequency component, and middle and high frequency components in green and blue, respectively. The high frequency components are seen to be more responsive to the narrow and thin parts of channels, while lower frequency components are more responsive to wide and thick parts of channels. Combining these frequency components together not only makes the overall morphology of the channel system clearer, but also makes it possible to analyze the heterogeneity of the channel and fan complex. This is illustrated for example by the frequency dependent definition of the internal architecture of the well-A fan.

Calibration with well

To validate and quantify the products of Spectral Decomposition of the 3-D seismic data, we calibrated these at the well-A location. A 1-D synthetic trace was generated using log and checkshot data from well-A, and tied with seismic data. This synthetic was then duplicated multiple times to generate a 40 X 40 trace sub-cube, which was placed symmetrically around the well-A. CWT spectral decomposition was then performed on the synthetic cube to generate frequency cubes with the same values as generated from the original 3-D seismic data. Corresponding cubes from the synthetic and seismic data were then compared for validation. The comparison showed similar tuning responses in corresponding frequency cubes, indicating the reliability of interpreted channel fan morphology and distribution.

Conclusion

Spectral decomposition of 3D stack seismic data was performed to interpret the morphology of the DD oil-bearing turbidite sands in the Barmer Basin. Blended frequency cubes from the decomposition capture the thickness variability and depositional architecture of sands within the turbidite channel and fan system. Results were validated through comparison with corresponding products of spectral decomposition of a 1-D synthetic generated at a well location within the seismic data. These results have provided greater confidence in appraisal well planning and field development.

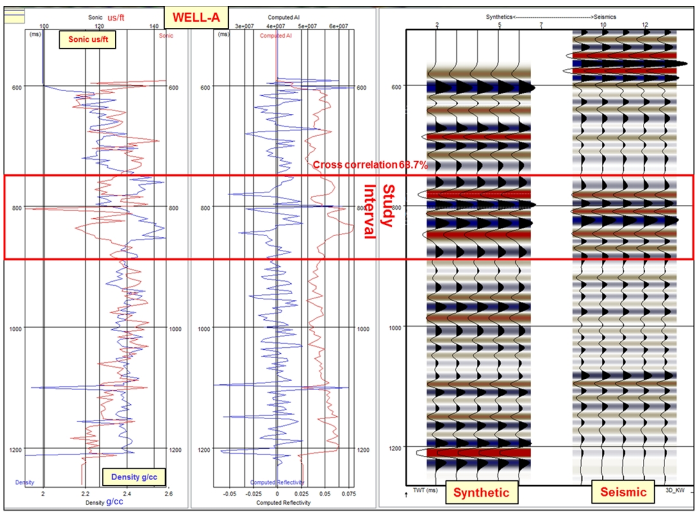

Figure-2: Well to seismic tie of Well-A with correlation coefficient of 68.7% at study interval with 25Hz central frequency Ricker wavelet.

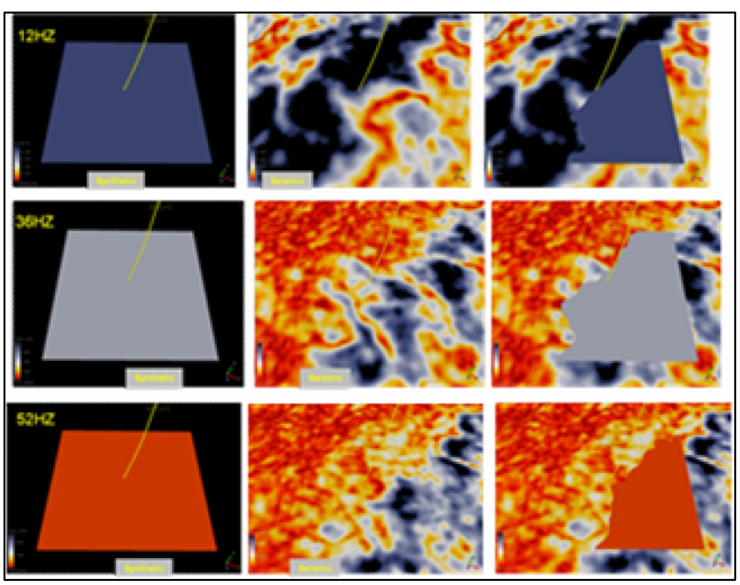

Figure-3: Well calibration showed good correlation between seismic and synthetic spectral responses

Interpretation of Subtle Channel-Fan system in Dharvi Dungar Formation of Barmer Basin, India using Calibrated Spectral Decomposition Data

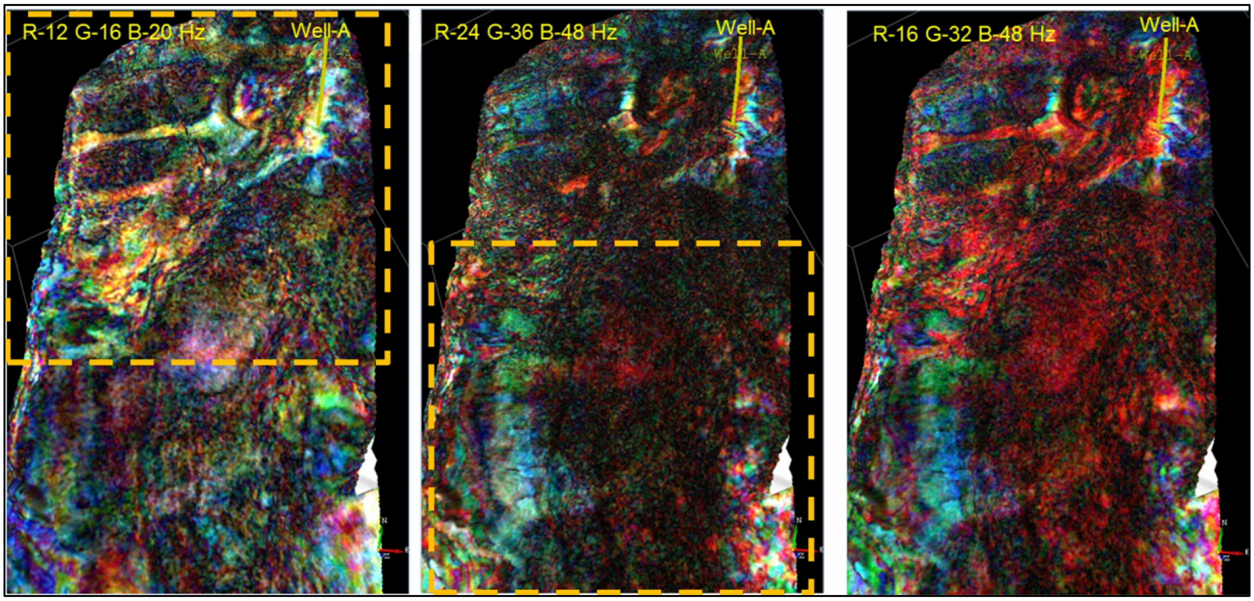

Figure-4: Spectral decomposition results of Low to High frequency blend established the entire channel-Fan system

Reference

Partyka, G. A., J. Gridley, and J. Lopez, 1999, Interpretational applications of spectral decomposition in reservoir characterization: The Leading Edge, **18**, 353-360.

Sinha, S., P. S. Routh, P. D. Anno, and J. P. Castagna, 2005, Spectral decomposition of seismic data with continuous-wavelet transforms: Geophysics, 70, 19–25.

John Dolson, V.Kothari, Bodapati Naidu V.R. Sunder and Stuart D. Burley, 2015 The discovery of the Barmer Basin, Rajasthan, India, and its petroleum geology, AAPG, Bulletin,v,99, pp 433-465

Acknowledgement

The authors are grateful to Cairn India limited and JV partner ONGC for permission to publish this paper. We have been extremely fortunate to be able to study and apply geophysical methods to extract geological information to have better understanding of the basin as part of exploration. We thank Vachaspati Kothari, senior Advisor Geology at Cairn for technical guidance during the project and for critically reviewing this study.