ID No. 2005060

Seismic attribute analysis of Rohtas Formation in Son Valley, Vindhyan Basin

N.K. Verma, T.K. Mistry, Nancy Jain, Sonu Kumar, Sapana Jaiswal, Prabhat Ranjan, Santanu Mukherjee, S. Mahanti, D.K. Srivastava & D.N. Singh

Frontier Basin, Oil and Natural Gas Corporation Limited, Kaulagarh Road, Dehradun-248195, Uttarakhand, India

E-mail: nkv56585@gmail.com

Abstract

Analysis of various seismic attributes including Average Absolute Amplitude (AAA), Average Instantaneous frequency and seismic impedance, incorporating the results of recently drilled wells in Son Valley, Vindhyan Basin, has led to a better understanding and prediction of possible reservoir distribution in the area. The strati-structural prospects, with fracture driven secondary porosity within Rohtas and Basal Kaimur sequences, exhibit moderately high seismic amplitude and low to moderate frequencies. Attribute maps corresponding to each of the three sub units within Rohtas Formation and the Basal Kaimur sand unit along with specific window based attributes corresponding to the gas bearing layers have helped in re-validating the existing exploratory locations and provided suitable leads for firming up new prospects within the study area. The Upper and Middle Rohtas Units were further subdivided into several proportional stratal slices and attribute maps for each of these stratal units superimposing the depth contours of the corresponding stratal tops have provided significant insight into the distribution of reservoir facies with respect to structural configuration.Analysis of spatial distribution of likely reservoir facies within Rohtas and Basal Kaimur assessed with the help of various seismic attributes, and integration with structural configuration, thickness patterns and petrophysical characters and testing data, has led to identification of a number of structural, strati-structural and stratigraphic prospects for future exploratory efforts in the area. Moreover, the seismic attribute maps have also been used for prognosticating the likely Inplace hydrocarbon volume of gas in the available acreages as well as around the pools established through gas bearing wells.

Introduction

As the conventional hydrocarbon reservoirs are declining and becoming matured worldwide, there is an increasingly greater dependency on producing oil and gas from unconventional fractured reservoirs. Seismic attributes have proved to be a very effective predictability tool for detecting fracture fairways and placing of wells within sweet spots of fractured reservoirs. The Son Valley sector of Proterozoic Vindhyan Basin in Central part of India has emerged as a potential hydrocarbon province with the recent discovery of gas from unconventional tight limestone and sandstone reservoirs within Rohtas and Basal Kaimur formations. Gas accumulation and flow potential in these reservoirs are primarily controlled by fractures.This paper presents the results of various seismic attribute analyses based on 2D seismic data, which has provided significant leads in predicting the distribution of the fractured reservoirs, identification of areas for future exploratory efforts and prognosticating the likely hydrocarbon volume for these unconventional gas plays.

Methodology

Various attributes based on seismic amplitude and frequency were mapped within different sub units and stratal layers of Rohtas and the Basal Kaimur units, as well as within specific seismic time windows corresponding to the established gas bearing layers. Post stack seismic inversion was carried out along key 2D seismic lines to capture the impedance response of the gas bearing fractured reservoirs. The results were analyzed by integrating with structural configuration, petrophysical character, fracture trends and testing data of drilled wells.

Seismic Attribute Analysis

Average Absolute Amplitude (AAA) maps corresponding to the three sub units within Rohtas Formation brought out the gross lithofacies distribution for each of these sub units (Fig.1).The AAA map of Lower Rohtas Unit shows the spread of high amplitude extensively in the entire area, suggesting a more or less uniform distribution of limestone. Patches of low amplitude are observed in the northern part suggesting the possibility of argillaceous facies within the Lower Rohtas Unit in that area. However, during the Middle Rohtas, the AAA map reveals a larger distribution of low amplitude particularly towards south of the study area, which is interpreted to represent the argillaceous limestone and shale dominated facies deposited under dominantly transgressive regime. The localized pods of moderate to high amplitudes represent the relatively cleaner limestone deposited in carbonate platform areas. The AAA map of Upper Rohtas Unit follows the distribution pattern of Lower Rohtas Unit to a large extent suggesting widespread deposition of limestone under a dominantly regressive phase. The map brings out the extent of moderate to high amplitude in the Nohta-Damoh corridor.

On calibrating the seismic events with GR and sonic logs of gas wells Nohta-A and B, the gas zone was observed to manifest itself as bright seismic amplitude with intervening dull amplitude and low to moderately low frequency (Fig.2). To chase this lead further, a number of prospects were drilled to probe similar bright to moderate amplitude and low frequency seismic anomalies. These are envisaged as strati-structural hydrocarbon accumulations primarily within fractured traps as well as associated with stratigraphic pinch outs. The drilling results have by and large validated the presence of gas insimilar seismic anomalies at different levels within Upper, Middle and Lower units of Rohtas Formation as well as Basal Kaimur Sandstone unit.

The seismic correlation with the lithofacies, fractures and gas occurrences in the so far drilled wells in Nohta-Damoh area has been made. AAA and Average Instantaneous frequency maps within specific windows corresponding to the established gas bearing fracture reservoirs within Upper, Middle and Lower Rohtas and Basal Kaimur revealed the spatial distribution of likely fractured reservoir facies in the study area The maps show that the amplitude values on the location of gas bearing fractured reservoirs is of the range 15000 to 18000 and the instantaneous frequency are of 24 Hz to 32 Hz suggesting a moderate to high amplitude and medium to low frequency for this seismic anomaly. Accordingly, the area has been subjected to amplitude and frequency analysis for the upcoming locations having similar characters. Analysis of the above attribute maps have helped in re-validating the existing exploratory locations and provided suitable leads for firming up new prospects within the study area. Moreover, these attribute maps were also used as inputs for estimation of Inplace hydrocarbon reserves for the established gas pools (Fig. 3 to 7).

Post Stack Seismic Inversion Analysis

Post stack seismic inversion studies using Hampson-Russell software was carried out for a better understanding of the reservoir quality. The well data of Nohta-A was used for calibrating the Post stack Inversion model.Sonic (DT) and Density (RHOB) logs were used for wavelet extraction. The seismic line PQ, passing through wells Nohta-A and B was taken as first reference line for model based inversion. After extraction of P-impedance trace at crossing point of other seismic lines with line PQ, inversion for P-impedance section of respective seismic lines has been carried out.

The study along the seismic line PQ, suggests that impedance of the Rohtas Limestone is of the order of 15000 to 18000 m/sec*gm/cc. Within this high impedance, there are number of low impedance zones having impedance values in the order of 9000 – 10000 m/sec*gm/cc (Fig.8). These low impedance zones correspond to the fractured gas bearing reservoirs encountered in wells Nohta-A and B. It is pertinent to mention here that high amplitude anomalies observed within Rohtas Limestone are generally represented by lowering of impedance in the inverted sections.This observation was further corroborated by presence of similar anomalies in wells Nohta-C and Damoh-

B (along the line RS) and Damoh-C (along line XY). The impedance sections of the above lines are placed as Fig. 8 and 9.

Discussion and Conclusions

Following observations have been made which may lead to the identification of future prospects within Rohtas Formation in the entire PEL area. The features can be identified based on:

1. Fault bounded strati-structural features with fracture driven secondary porosity development exhibiting high amplitude and low to moderate frequencies.
2. Structural/strati-structural features on the flank areas of the major highs/lows related with regional faulting having proper sealing, characterised by varying amplitude and frequencies.
3. Stratigraphic wedge out features against the Damoh high may be the favoured ones. Similar wedge out features are not seen around Jabera high within the PEL area.
4. The thick bottom limestone section showing likely development of fractures even exhibiting high amplitude and high frequencies.
5. Basal part of the Kaimur Formation for numerous sandstone layers even having low amplitude and low to high frequencies.
6. The lowering of impedance within the different units of Rohtas Formation, well calibrated with a number of gas bearing fractured reservoirs may also be one of the criteria to firm up the prospective locale (Fig.10).

Acknowledgement

The authors are grateful to Director (E) ONGC for his kind permission to publish this paper. The authors also express their gratitude to Basin Manager, Frontier Basin, ONGC, for his guidance and continued motivation for the study. The views expressed in the paper are of the authors only and not necessarily of the organization they represent.

References

Robert Godfrey and Ran Bachrach, 2008: Seismically guided fracture characterization, CSEG Recorder.

Schoenberg, M., and Sayers, C.M., 1995, Seismic anisotropy of fractured rock: Geophysics, 60, 204-211.

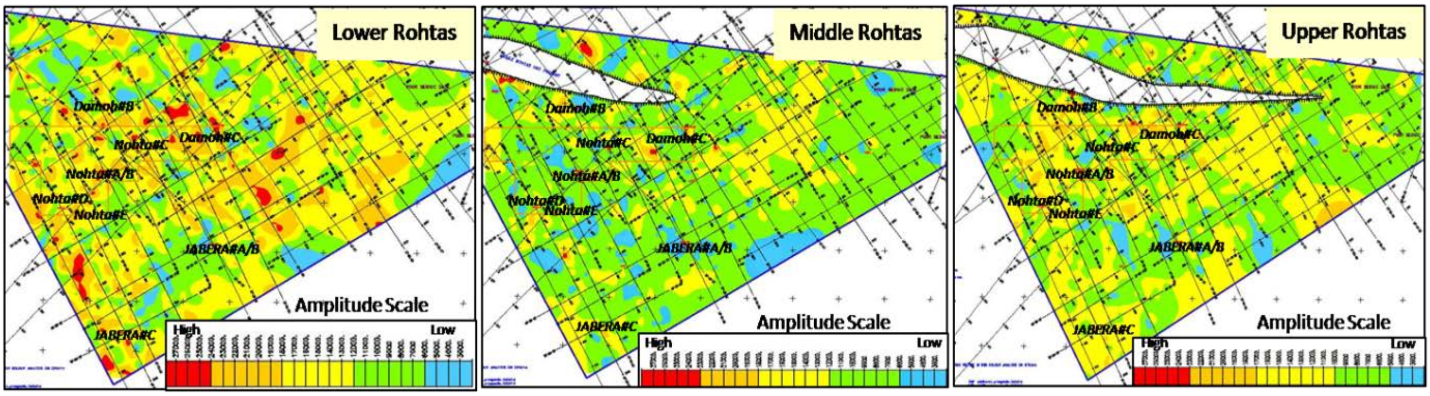


Fig.1 Average Absolute Amplitude maps of Upper, Middle and Lower Rohtas Units

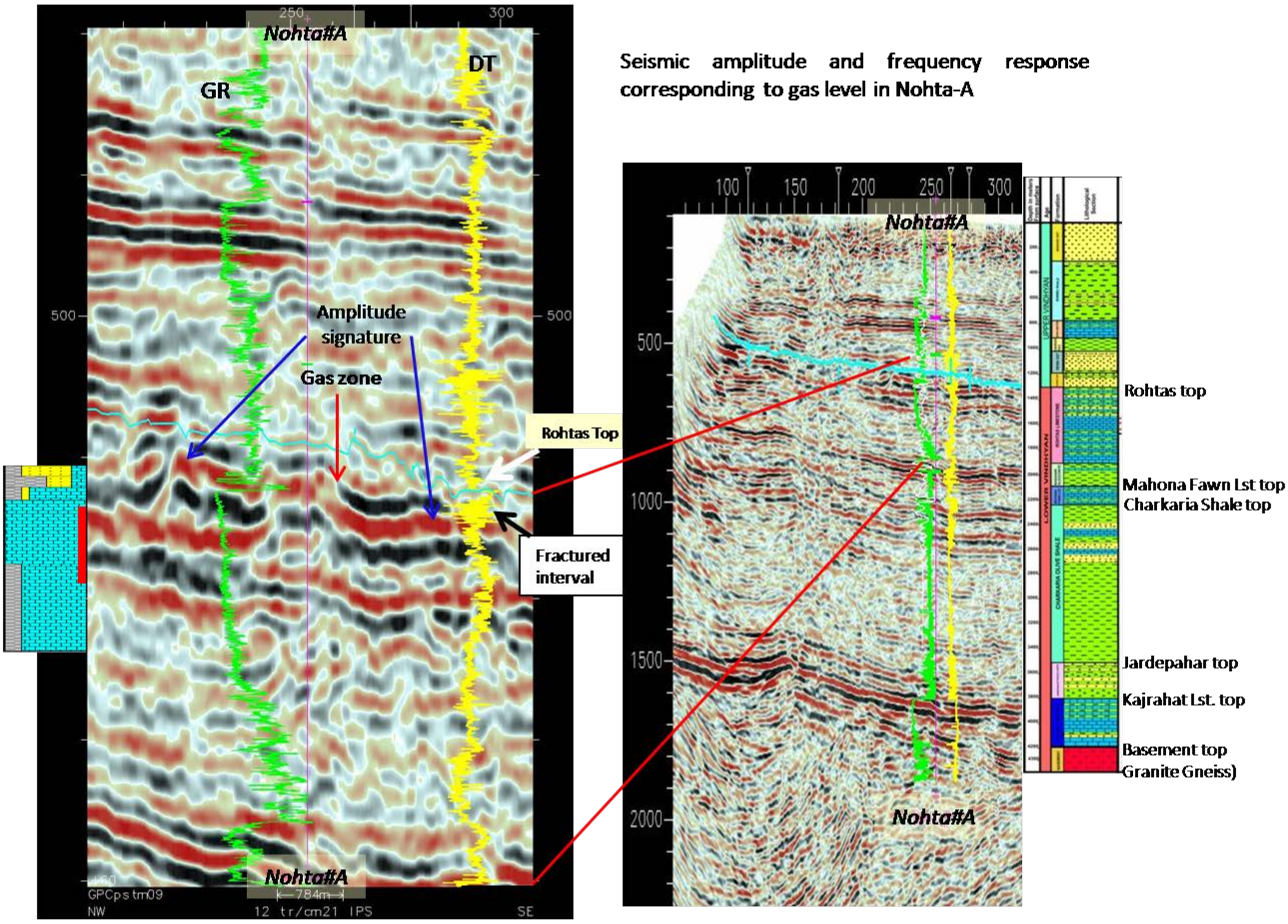
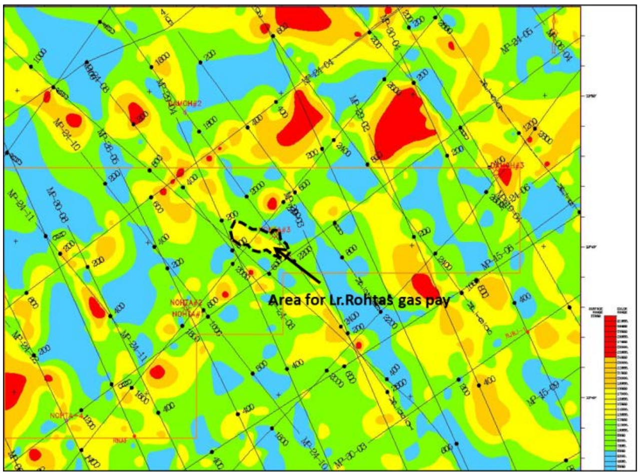


Fig.2 Calibration of seismic amplitude response of gas bearing fractured limestone reservoir in well Nohta-A



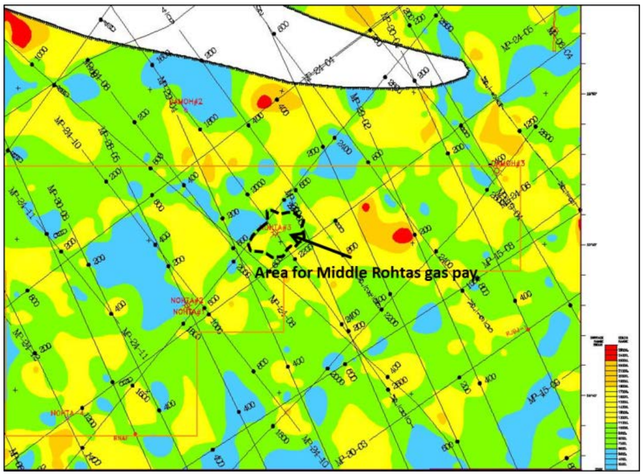
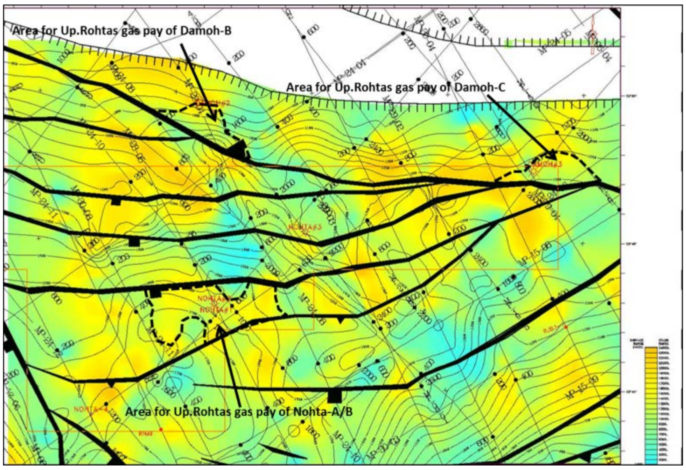


Fig.3 AAA Map corresponding to the window of Lower Rohtas gas pay showing its areal extent

Fig.4 AAA Map corresponding to the window of Middle Rohtas gas pay showing its areal extent



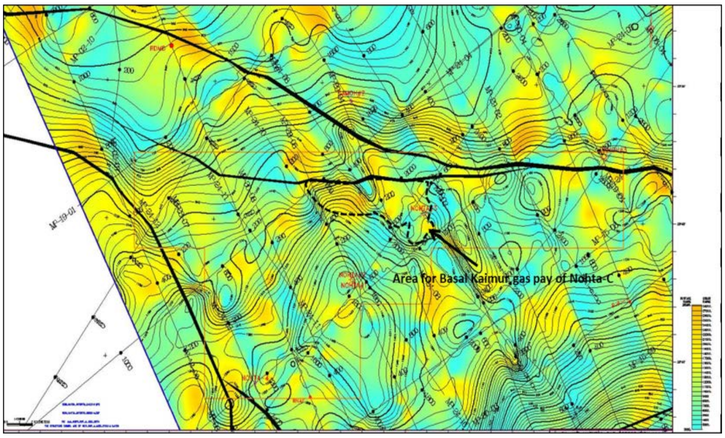


Fig.5 AAA Map corresponding to the window of Upper Rohtas gas pay showing its areal extent

Fig.6 AAA Map corresponding to the window of Basal Kaimur gas pay showing its areal extent

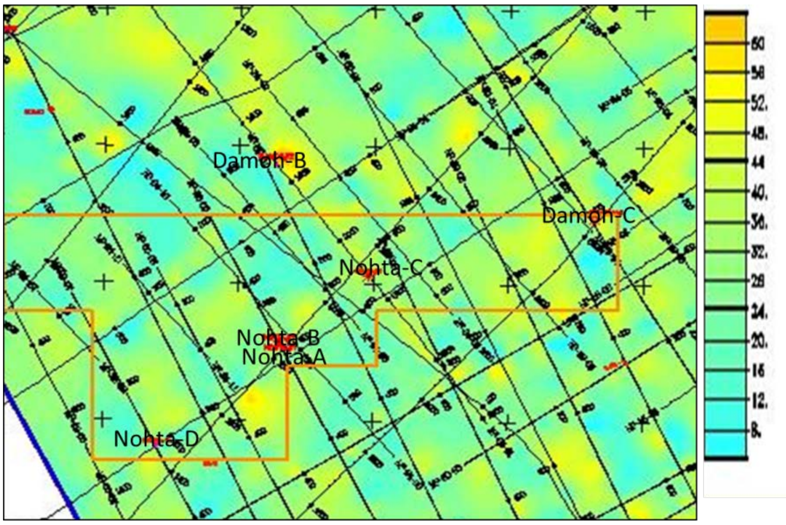


Fig.7 Average Instantaneous Frequency Map corresponding to the window of Upper Rohtas gas pay. The gas bearing wells show a frequency range of 24-32 Hz

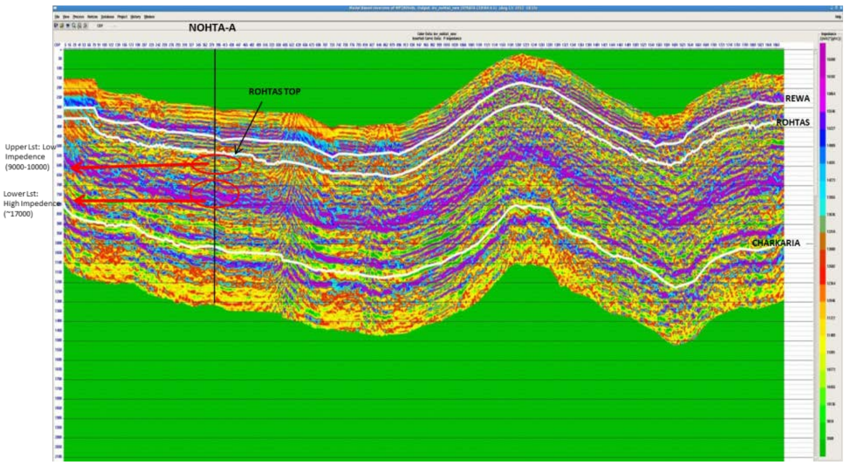


Fig.8 Calibration of impedance response along seismic line PQ through gas wells Nohta-A and B

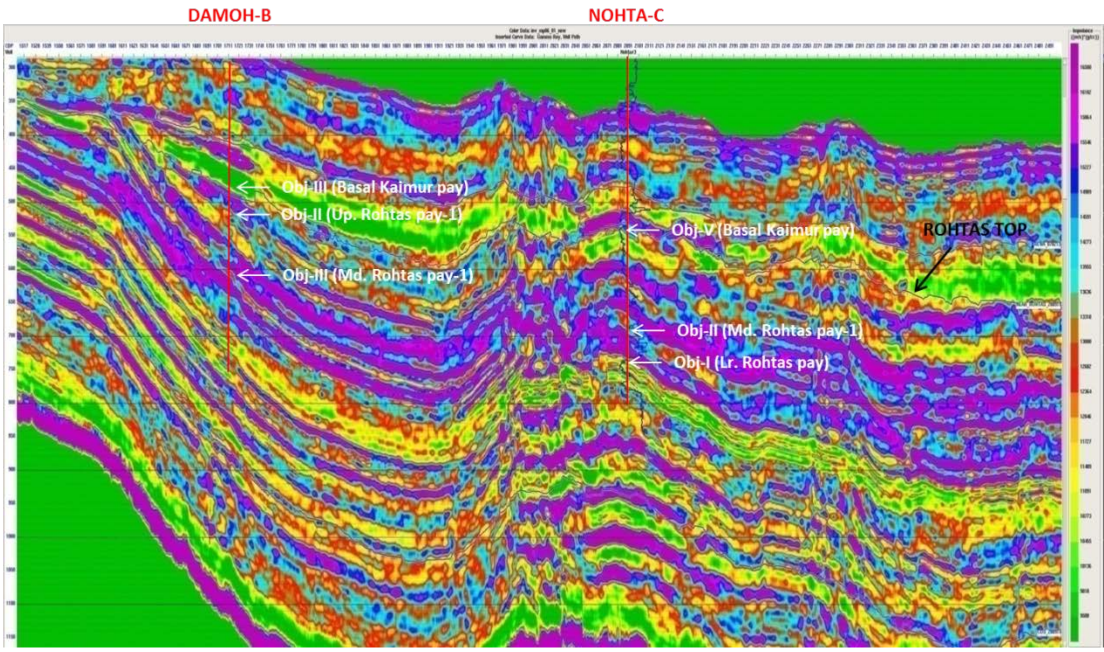


Fig.9 Lowering of impedance in gas bearing fractured reservoirs in wells Damoh-B and Nohta-C

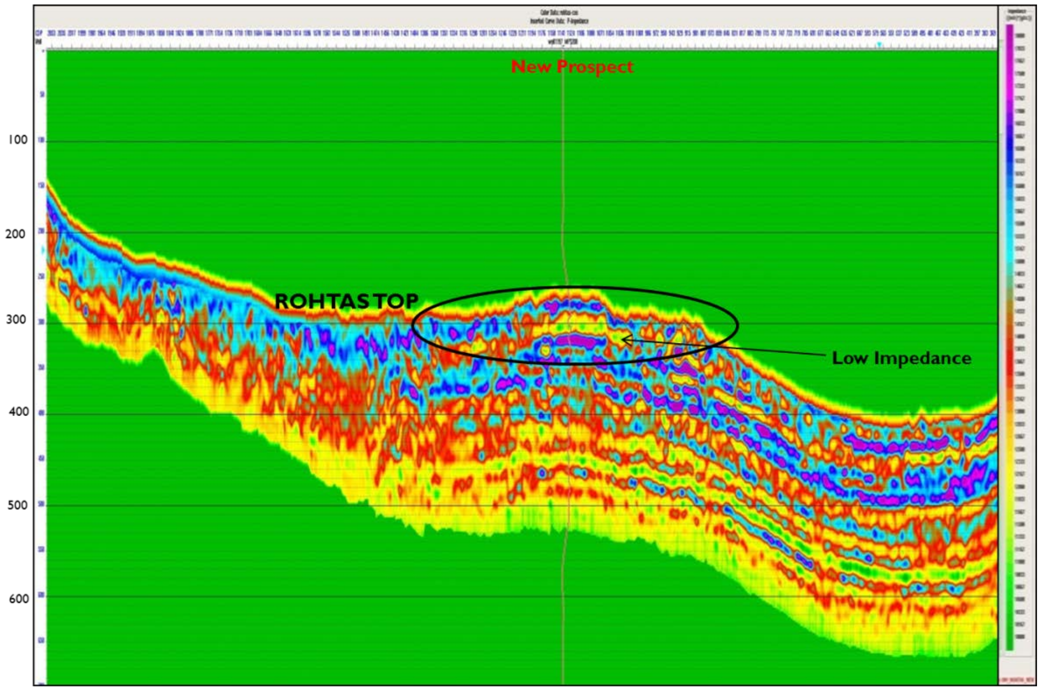


Fig.9 New prospect identified based low impedance anomaly within Rohtas Limestone