New insights to Neelam-Heera fields challenges using ocean bottom node seismic interpretation

Uday Shanker Mishra[1], Pragya Shukla, Souvik Sengupta, Saumya Goswami, Bidyut Chowdhury, Abhimanyu Maitra, Vishal Mulchandani, Anubrati Mukherjee, Subhankar Basu, Srilata Mahapatra, Anand Prakash, Vikash Saluja
[1] Email: udaymishra4002@gmail.com, Schlumberger

Abstract

Neelam-Heera (NH) fields are located in the Panna-Bassein block of the Mumbai offshore basin and are significant contributors to India's oil and gas production. These mature oil and gas fields are producing mainly from Eocene-Oligocene carbonate reservoirs with established carbonate plays in this area. Key challenges of NH fields include seismic imaging issues in areas perturbed by shallow gas along with faults, discrepancy in time and depth structures caused by huge lateral and vertical velocity variations, and delineation of karst/discontinuities in the Neelam Bassein Formation to improve well planning and avoid mud loss. The seismic interpretation study we conducted used recent ocean bottom node (OBN) seismic data to provide new insights to these challenges and are discussed in this paper.

Introduction

The Neelam Field was discovered in January 1987 and is located about 45 km west of the Mumbai coast, in about 55 m water depth. It is the third largest field after Mumbai High and Heera fields of the Western Offshore basin of India. The field was confirmed with the drilling of appraisal well located midway in a saddle between the field's two culminations in the east and west. Two pay zones in the form of the Bassein (oil and gas) and Mukta (gas) formations are present at Neelam and lie within a sedimentary sequence of 2216 m. The fields borders are defined by the north-south trending fault in the east and the oil/water contact along its western edge. The Heera Field is located offshore in the Basin, approximately 70 km to the southwest of Mumbai City and approximately 50 km to the south of the Bassein Field in the eastern Arabian Sea. The field was discovered in October 1977 after the exploratory well Alibag-1 encountered oil from the Mukta Formation and gas from the Ratnagiri Formation. The structure of the Heera Field consists of a north-south-trending anticline and a major fault oriented northwest-southeast that limits the reservoirs on the eastern flank of the structure. The structural province of Mumbai Offshore Basin, location of NH fields, and key reservoir depth structure map showing the structural configuration of the NH area are illustrated in Figure 1.

Oil and Natural Gas Corporation (ONGC) acquired 3D OBN (four-component) data in the NH area during 2019 (Ghara, 2020). The area of operations was approximately 80 km west of Mumbai located in the Arabian Sea, with the OBN area covering 750 km^2. WesternGeco was awarded the integrated project for processing, inversion, and interpretation in 2019. Subsequently, detailed seismic interpretation was carried out in NH fields for structural/stratigraphic interpretation and reservoir characterization to provide insights from the new data to solve field challenges.

In this paper we will discuss the insights derived from seismic interpretation of newly acquired and processed OBN data to solve three key field challenges: 1) poor seismic imaging below shallow gas in Heera, 2) discrepancy in time and depth structure caused by shallow velocity variations, and 3) delineation of karst/discontinuities in the Neelam Bassein Formation for improved well planning (Ghosh, 2018).

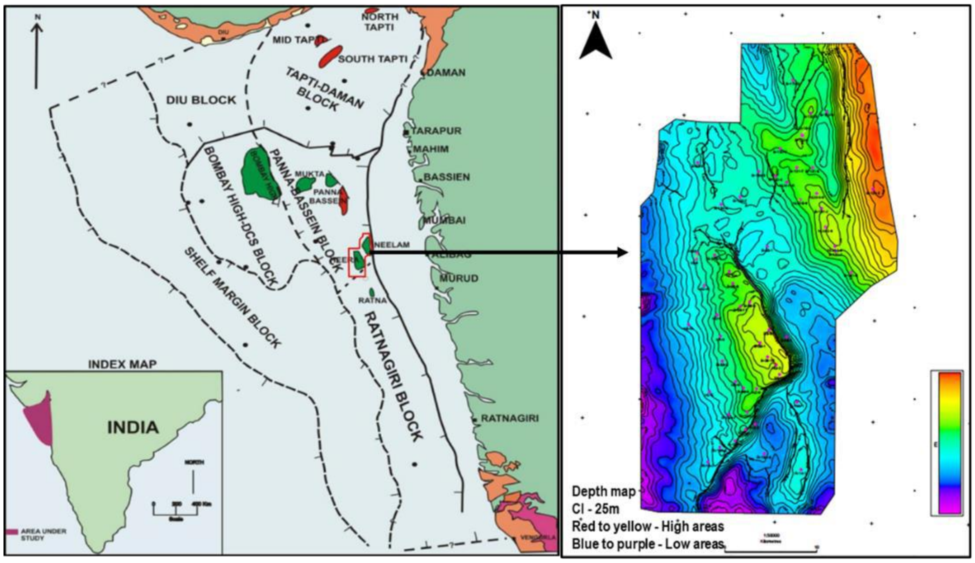

Figure 1: Mumbai Offshore Basin overall structural provinces (after Pandey et al., 1998) alonwith NH fields highlighted in red polygon (left). Reservoir depth structure map showing structural configuration of NH area (right).

Imaging improvement using PP-PS seismic data

A significant improvement is seen in the imaging of the NH area because of prestack depth migration (PSDM) processing of OBN data, which led to detailed mapping and understanding of various formations such as Bandra, Alibagh, Heera, Mukta, Bassein, Panna and Basement. Some of key improvements are highlighted in Fig 2 which shows huge improvement in fault definition, unconformity/erosional truncations, geological features, key reflectors definition and continuity.

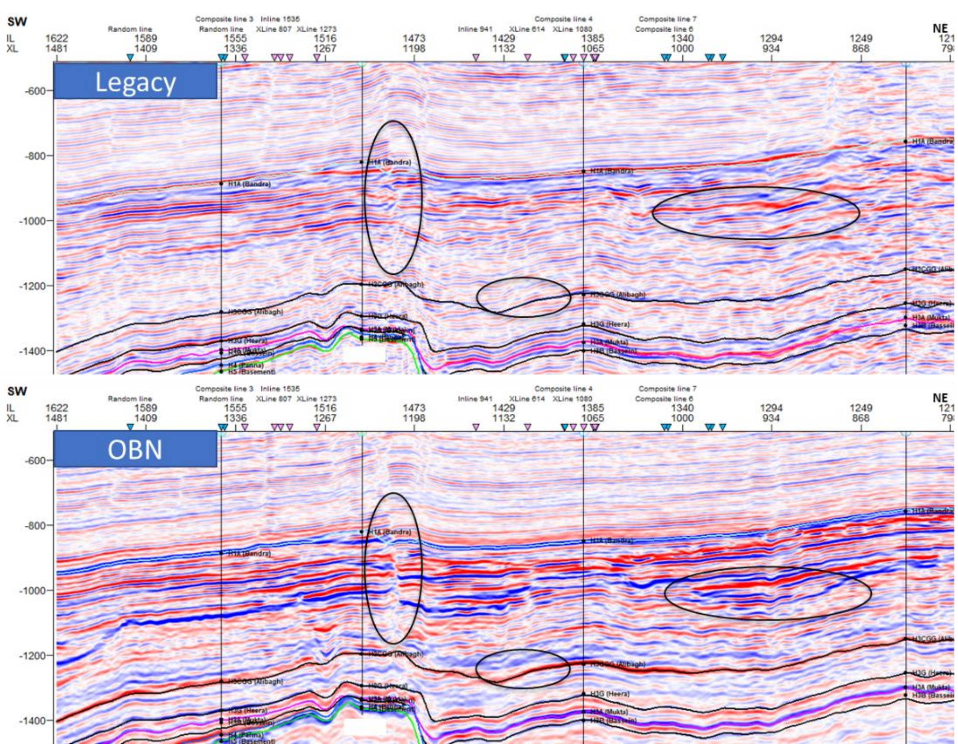

Figure 2: Comparison of Legacy vs OBN data showing significant improvement in fault,

horizon and geological feature definition in OBN data.

One of the key challenges was to understand the structural changes in areas masked by shallow gas clouds in the Heera high area. The PP data could not provide clear imaging of areas masked by shallow gas; however, PS data could provide imaging below the gas cloud, as shown in Figure 3. The gas bearing Bandra Formation in the crestal part of the Heera field which overlies the Bombay Formation and consists mainly of limestone with shale bands is mapped properly with help of PS data. This key advantage of OBN data in NH, where both PP and PS seismic are available, helped improve seismic interpretation of reservoir intervals and improve future development planning.

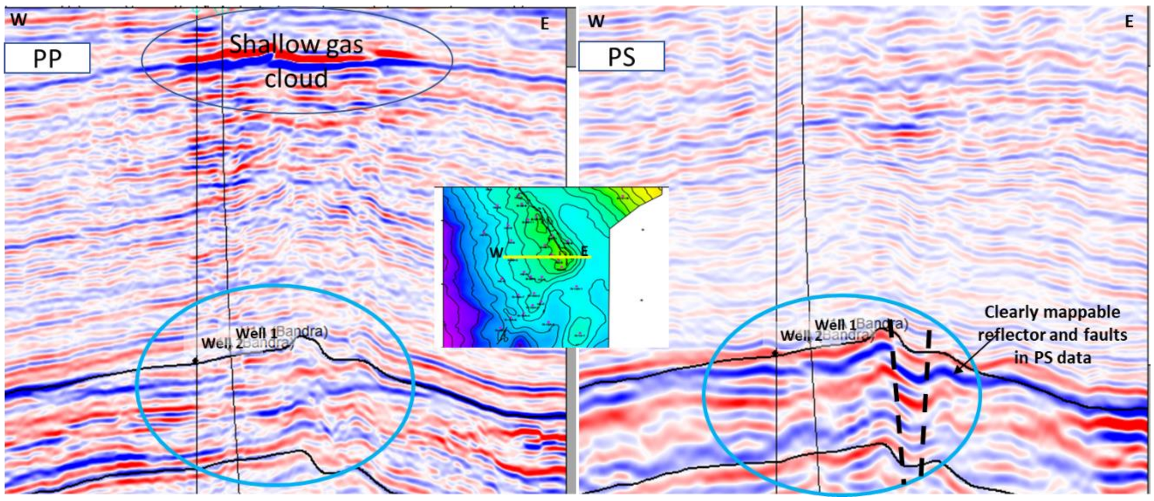

Figure 3: West-east seismic section showing shallow gas cloud and poor imaging on PP data (left); however, significant improvement leading to better horizon and fault definition can be seen on PS section (right).

Improved structural understanding with high- resolution velocity from processing

The NH area shows prominent trends related to a velocity anomaly at a shallow level (dissolution features), forming the valleys in the time cube that are not present in the depth cube (seismic velocity slice and profile showing large-scale velocity anomalies in Figure 4). The key formations Bandra, Alibagh, Heera, Mukta, Bassein, Panna and Basement are mapped carefully with integration of both time and depth cubes used for interpretation. Additionally, a new seismic marker between Bandra and Alibagh is picked to understand the velocity artifacts in time cube as it represents a sequence boundary showing erosional truncations and soft filling of very low velocity compared to background. The surgical mapping of Heera and Panna formations in thin pinch-out areas of Heera high with consideration of keeping low time residual helped as high quality surface for velocity modeling. After interpretation a 3D grid based velocity model is prepared using high resolution seismic velocity, Time-Depth relations and well tops. The new depth maps that resulted provide insights in areas hindered by previous false structures, especially in the Heera area, and are key to a future development model update. The time and depth map comparison are shown in Figure 4.

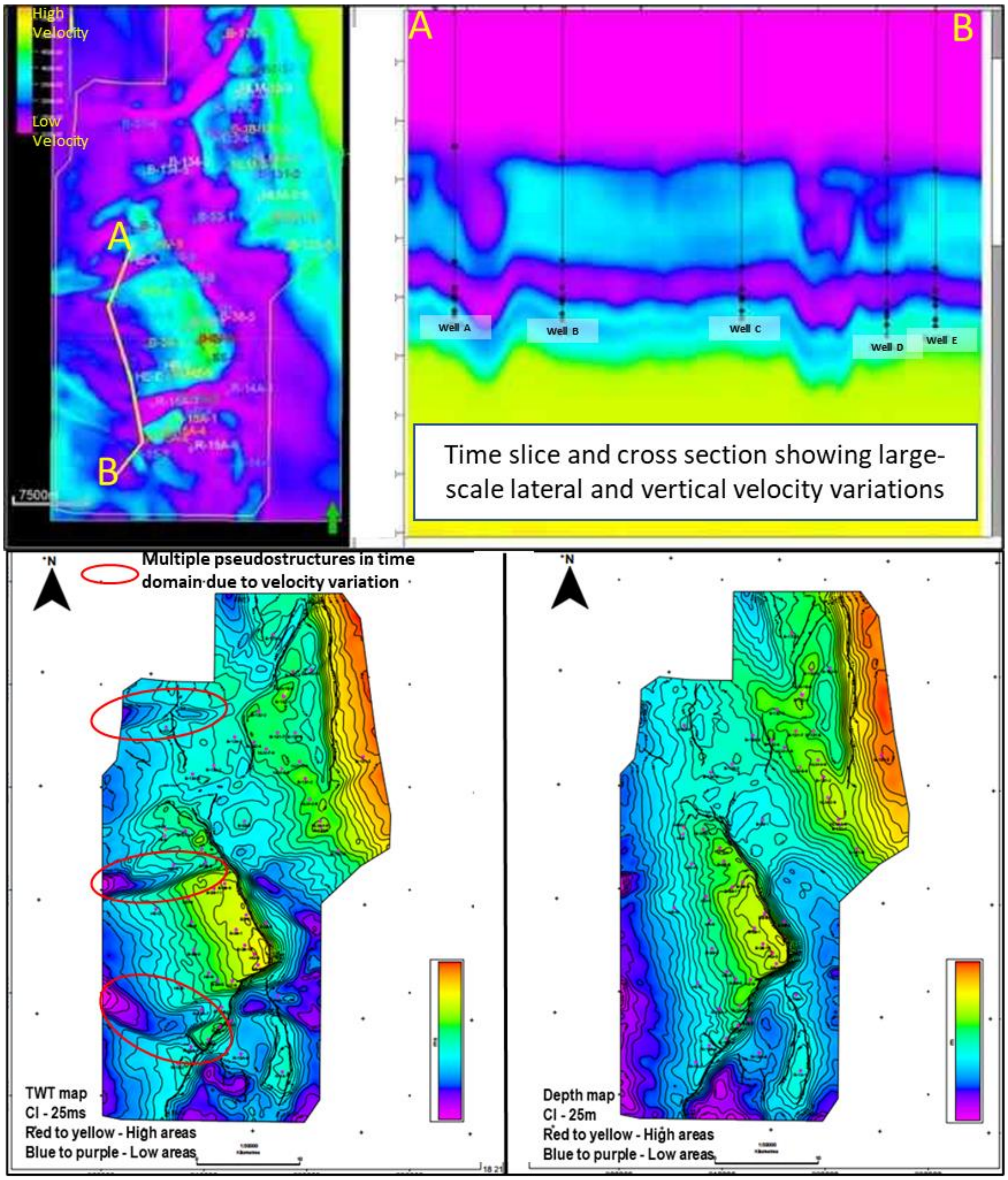

Figure 4: High-resolution velocity showing large-scale lateral/vertical velocity variations causing pseudostructures in time map, which are corrected in the depth map.

Integrated understanding of Neelam karst/discontinuities

To gain insights on karstification and issues related to mud loss in Neelam Field (Bassein Formation), various structural attributes were derived and correlated with available well data. The attribute study improved our understanding of mud-loss issues in Neelam Field (Bassein Formation) and how local tectonic events might have increased karstification. Generally, karst features enhance the secondary porosity in carbonates, and may cause none to minor mud loss while drilling. However, karst in combination with structural features, such as faults and fractures, in tectonically disturbed regions can lead to heavy mud loss.

To identify karstification and tectonically disturbed areas in the Neelam Bassein Formation, the following attributes were used:

1- Variance maps at different azimuthal stacks were derived and posted with well mud loss information to identify fault/lineaments/fracture directions and validation of mud loss wells. These suggested that the wells with mud losses were falling at discontinuities, as highlighted in Figure 5.

2- Most positive curvature and most negative curvature attributes at different azimuthal stacks alongside variance maps, provided detailed high-resolution insights on faults/lineaments/fractures, and posting of well mud-loss information, validated the disturbed-zone-related mud-loss areas.

The combination of curvature and variance attributes proved to be a highly effective tool in identifying the karst- and tectonic-related discontinuities in Neelam, and is key to future well planning. Incorporating this insight, the recommendation for future wells includes well planning using attribute maps at different azimuths to avoid mud loss.

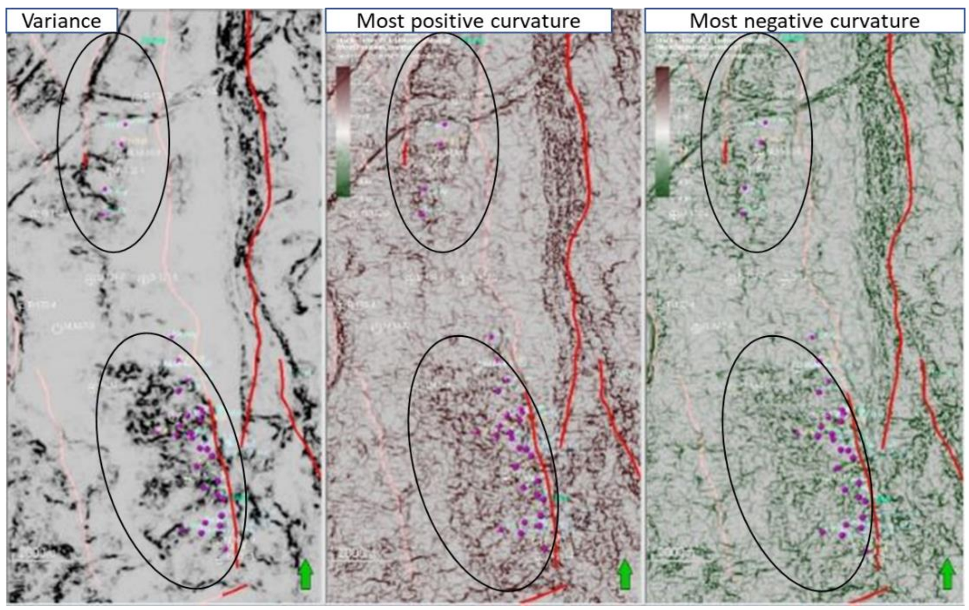

Figure 5: Variance, most positive, and most negative curvature attributes highlighting the highly karstified northern and southern sectors in the Neelam area (pink dots on map represent wells with losses).

Conclusions

The availability of OBN multicomponent seismic data with high-quality processing and imaging, and subsequent detailed seismic interpretation of NH fields using PP and PS data, provided new insights to solve the key challenges of NH fields. The key outcome of this study includes an improved understanding of areas perturbed by shallow gas by using both PP and PS data for seismic interpretation, and better depth maps for integration into the future development model in areas with discrepancies caused by significant lateral and vertical velocity variations. In addition, we were better able to delineate karst/discontinuities in the Neelam Bassein Formation, which improved well planning and helped avoid mud loss.

Acknowledgment

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