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UNDESTANDING HIGH IMPEDANCE RESERVOIR SANDS OF MAHUVA FORMATION IN C39 FIELD, WESTERN OFFSHORE BASIN INDIA

Abstract:

An innovative approach to discriminate the lithology and fluid in C39 field was adopted using the individual well to classify the elastic property of gas as well as that of water bearing sands of Mahuva Formation of Oligocene age. These reservoir sands are thin and discrete and also being high impedance sands makes them difficult to understand. Issues during development drilling brought out this fact very clearly. Earlier attempts to understand and discriminate the facies and fluid could not be successfully achieved due to poor quality of seismic dataset as well as lack DSI logs. Improved seismic resulted in much higher quality of pre-stack Inversion results and DSI log from one development well helped in improving the understanding of this reservoir sand.

Introduction:

C39 field of Tapti Daman Sector of Mumbai Offshore is located in the northern most part of C Series ML held by ONGC (Fig.1). Exploratory drilling activities in the area started in December 1995 by drilling of 8 exploratory wells (C-1 to C-8) based on G&G data analysis of 2D seismic data (Fig. 2). As a result hydrocarbon pools were established in Daman and Mahuva formation of Oligocene age. To chase these pay sands 1680 SKM of 3D OBC data was acquired in 1999-2000 field season. This was one of the earliest OBC data acquisitions in this part of the world. Integrating this seismic with existing well data five more wells were drilled in the area establishing more hydrocarbon pools. These hydrocarbon pools were understood to have been expressed well through sweetness attribute on seismic data (Fig. 1). Taking lead from exploratory input main pay sand of Mahuva Formation was undertaken for development in 2008-09. One platform with six slots was put up for production from this pay sand. In the Initial phase of development drilling, two wells, one each close to exploratory wells C-6 & C-8 were planned and four wells up-dip of the established reservoir were drilled. The four up-dip wells had issued with either reservoir thickness or fluid content. As a consequence, a reservoir characterisation project was taken up to understand the fluid and facies characters of this pay sand.

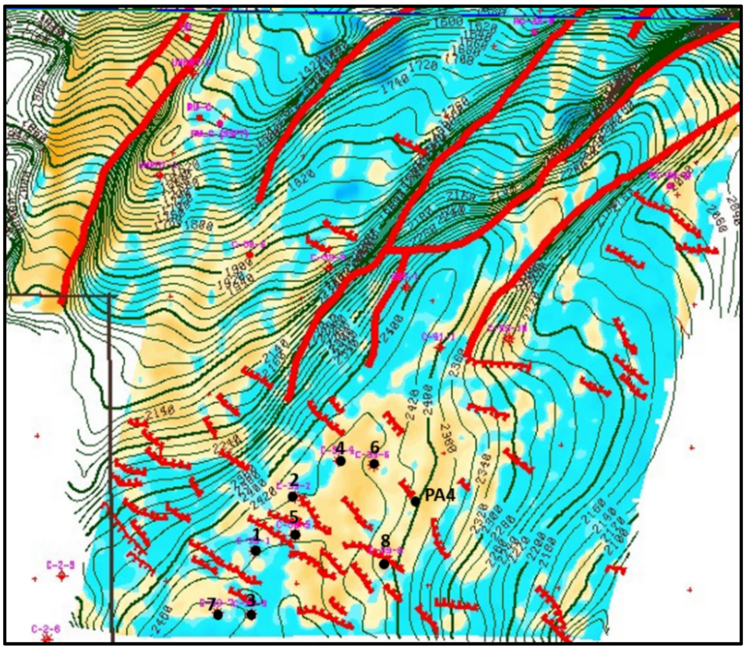


Fig. 1 Map showing study area (C39 Field)

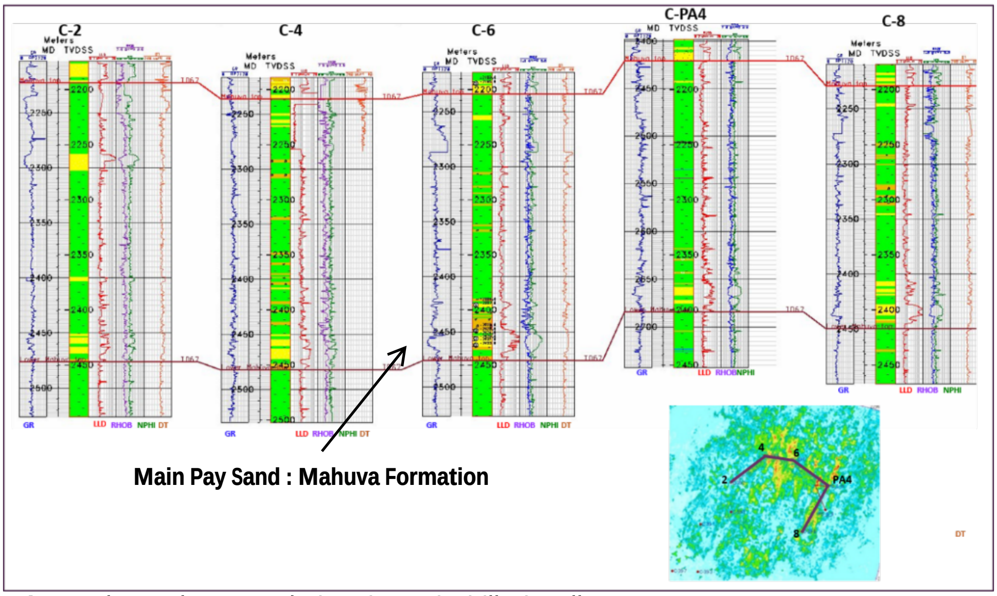


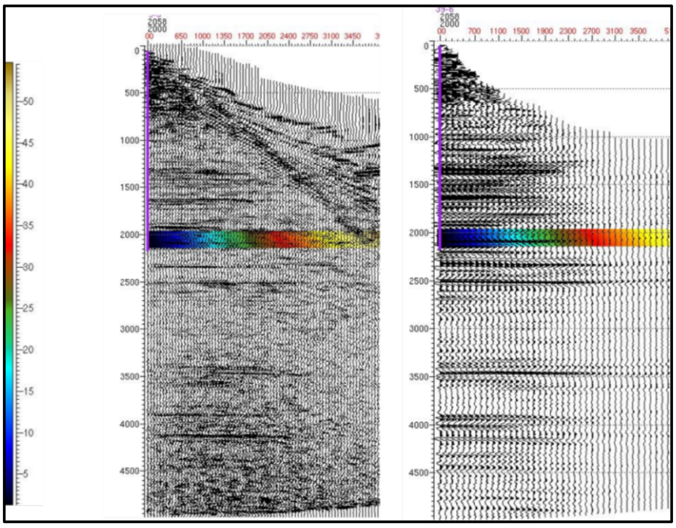
Fig. 2 Electro-log Correlation through drilled wells

Previous Study:

For the reservoir characterisation project partial stack seismic data, seismic velocities, well log data and horizon interpretation were combined within the simultaneous inversion workflow to produce a model of elastic properties for C-39 field. These elastic properties have been interpreted qualitatively in terms of sand distribution. The quality of the inversion results are determined by the quality of the seismic data. The limitation on the interpretation of the inversion results is dependent on the quality and resolution of the seismic data and also on the petrophysical properties of the rocks. The quality of the seismic data is primarily affected by the acquisition. The OBC layout was such that significant acquisition footprint were present at the interval of interest. In addition, the seismic data also suffer from incomplete move out removal and distorted bandwidth. The sands in the interval of interest are generally below seismic resolution same for the sands of the Mahuva formation. These sands tend to exhibit Class I to Class II AVO as they have relatively high p-impedance and low Vp/Vs (Fig. 3) compared with the bounding rocks. The water bearing sands tend to Class I and the gas bearing sands to Class II. This issue restricted the objective of discrimination only of the reservoir facies and not the fluid and facies discrimination (Fig. 3).

Fig. 3 Simultaneous Inversion using partial stacks demonstrating facies discrimination

Present Work:



To address the issue of fluid discrimination along with that of lithology was taken up starting with improvement in quality of seismic data which inherited a strong amount of acquisition foot prints and significant noise. Reprocessed seismic data (Fig. 4) appeared to be of much better than the original volume and also it can be noted to have signal present at about 35° or higher at the objective interval. The improved data set was utilised to generate five partial angle stacks starting from 0° through 35°. Structural framework involving the seismic horizons corresponding to Daman Top, Mahuva Top and Lower Mahuva Top were used.

Fig. 4 Improved Seismic Dataset

Reservoir sand corresponding to Mahuva Formation is bounded between Mahuva Top and Lower Mahuva Top horizon, and overlies Lower Mahuva Top surface. Log data from all the available exploratory wells and one of the development well (C-PA4) having DSI, coupled with C-2, C-6, C-7 & C-8 were used for generating well to seismic ties and generating wavelet for pre-stack inversion. A very robust low frequency model along with stringent QC check (Fig. 5 & 6) to set parameters for pre-stack inversion resulted in output of P-Impedance, Vp/Vs and other derivative volumes of elastic properties.

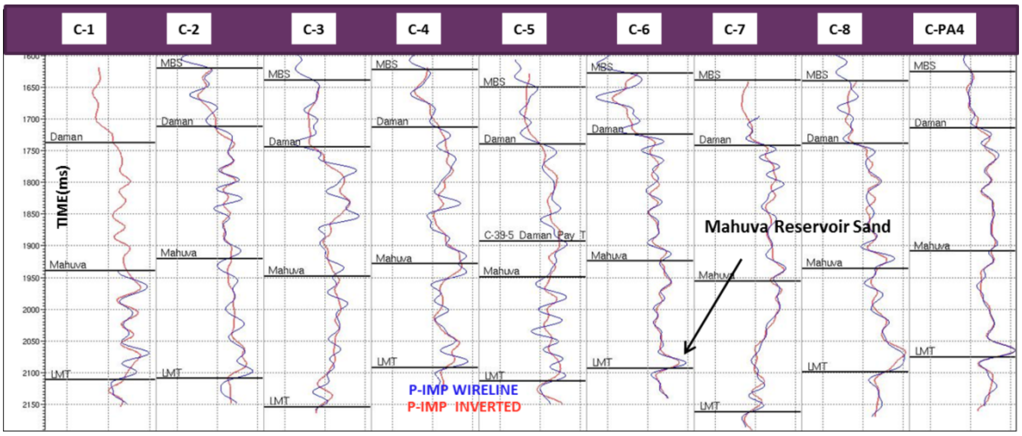


Fig. 5 P-Impedance Logs from recorded data and from Inverted data

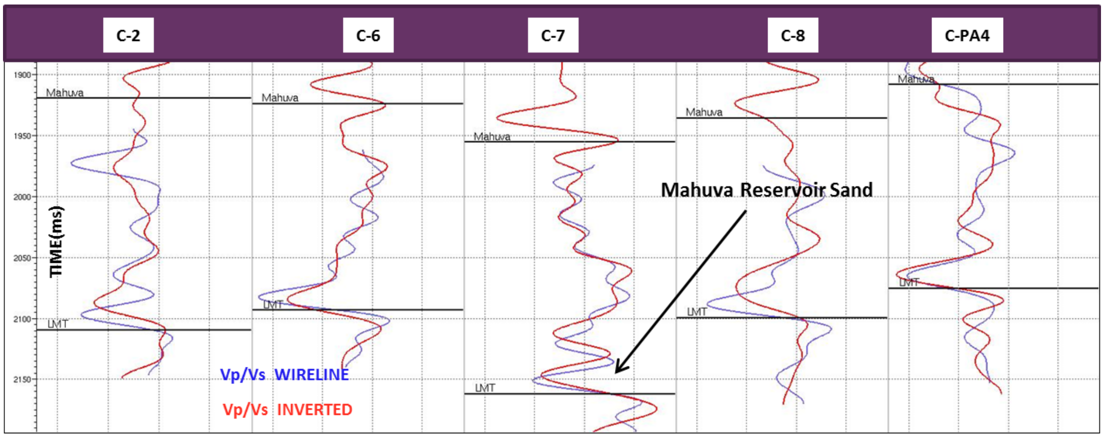


Fig. 6 Vp/Vs logs from recorded data and from Inverted data

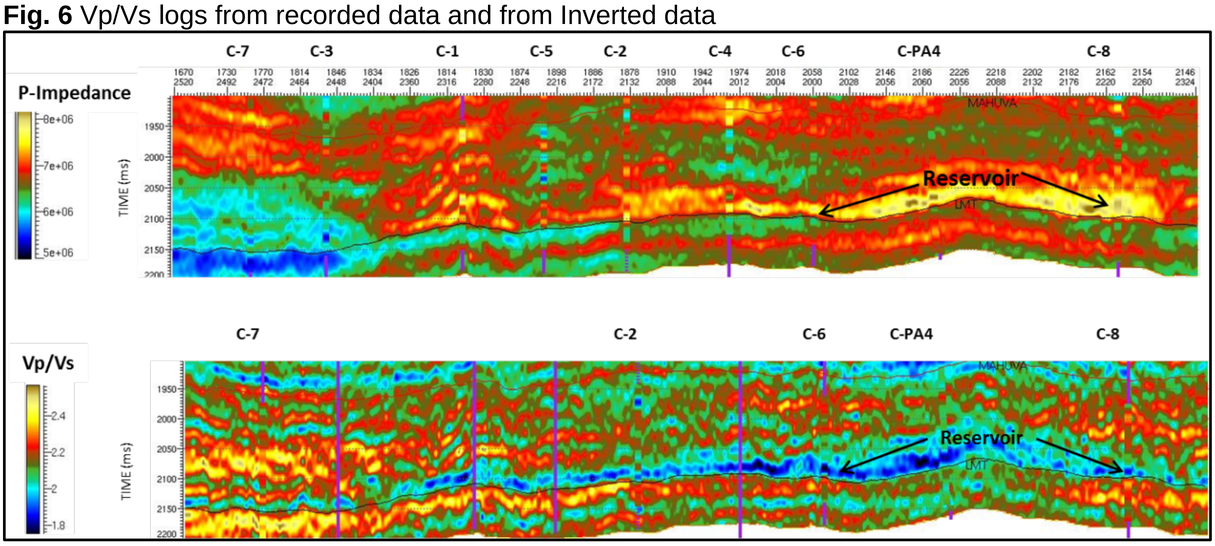


Fig. 7 An arbitrary section through wells showing Pre Stack Inversion Output

Complex nature of this reservoir sand can be exhibited through comparison of well logs of the exploratory well C-6 and a development well C-PA1 drilled to target this paysand at about 80m offset to the exploratory well (Fig. 8). In such a short distance from the exploratory well, the sand in development well (C-PA1) is gas bearing and has a GWC shallower than the top of paysand of exploratory well C-6 (Fig. 8). Also a sand in development well C-PA4 though structurally higher turned out to be water bearing. This leads to one important conclusion that these sands are not only thin and discrete in nature they all appear to be having individual entrapments.

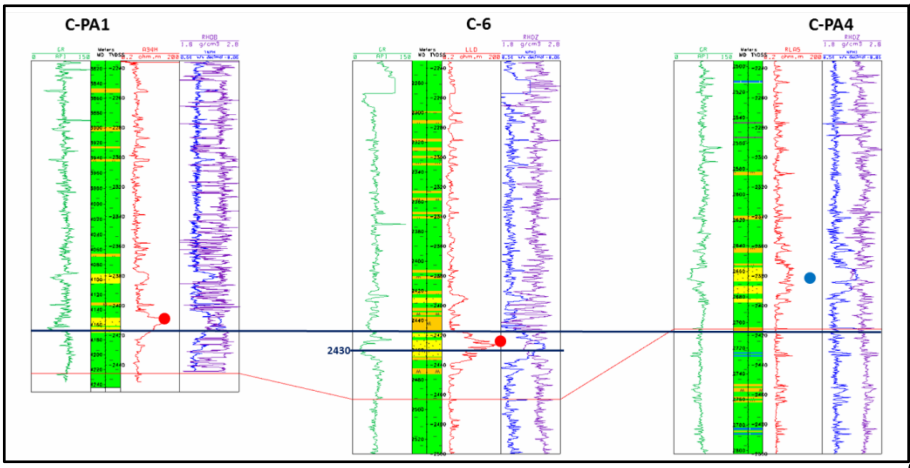


Fig. 8 Electrolog correlation of an exploratory and two development wells

DSI log from this water bearing sand in well C-PA4 came in handy in separating gas bearing sands from that of water bearing sands.

Interpretation of Inversion Analysis:

Four exploratory wells namely C-2, C-4, C-6 & C-8 and one development well C-PA4 were used in cross plot analysis of logs extracted from the inverted inversion results (Fig. 9). Taking all the five wells into cross plot analysis led to a trend line that separates shales from sands, both water bearing as well as gas bearing. The half on the left side of this trend line denotes shale facies and the one on the right of this trend line represents reservoir facies having either gas or water. However, the half on the right hand side represent three sands, two from hydrocarbon bearing paysands from wells C-6 & C-8 and one from water bearing sand of well C-PA4 (Fig. 9). Creating polygons of P-Impedance and Vp/Vs values individually from these three sands resulted in generation of geobodies those either representing gas bearing sands or that of water bearing (Fig.10).

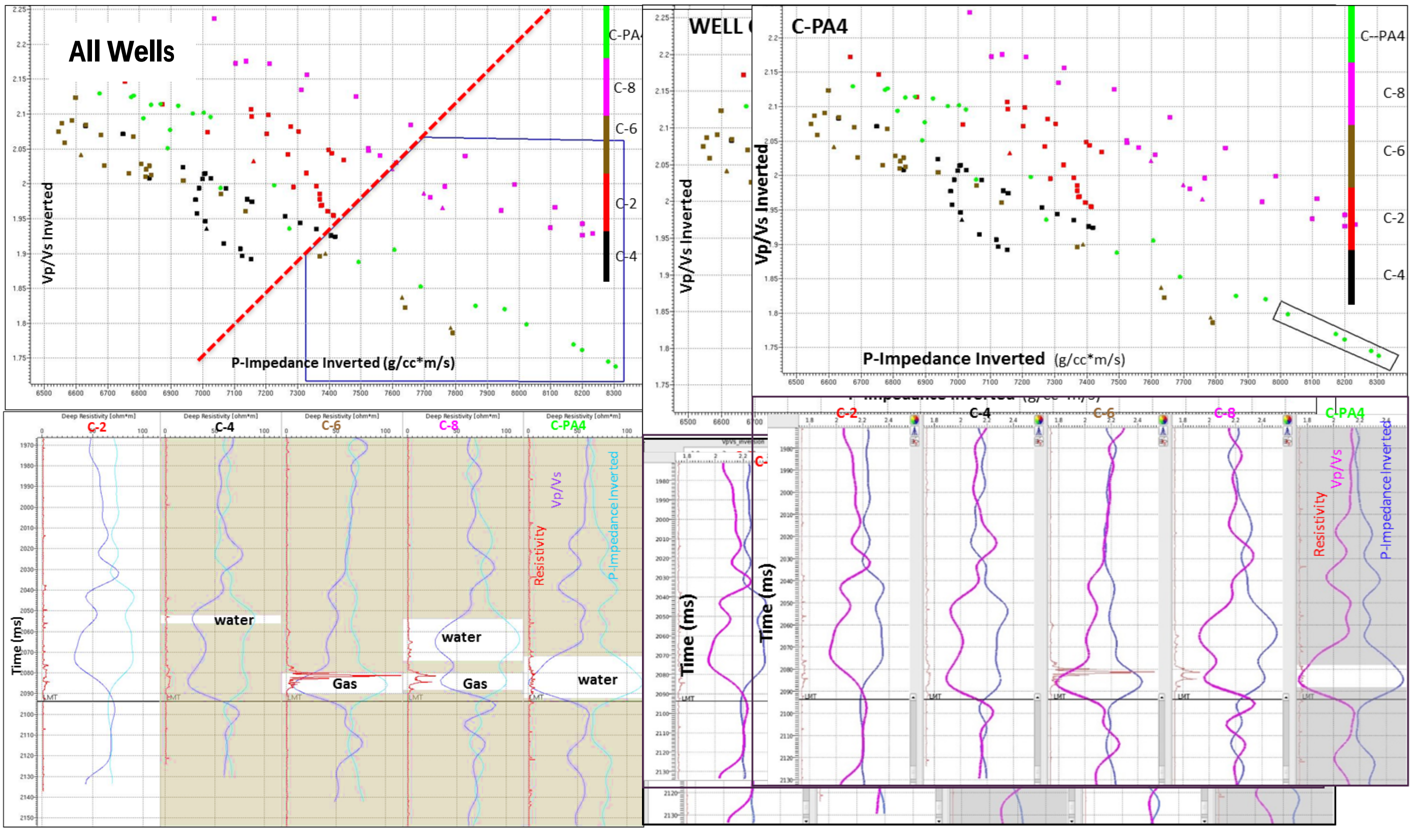


Fig. 9 Cross plot analysis of P-Impedance vs Vp/Vs from extracted logs of Inverted volumes

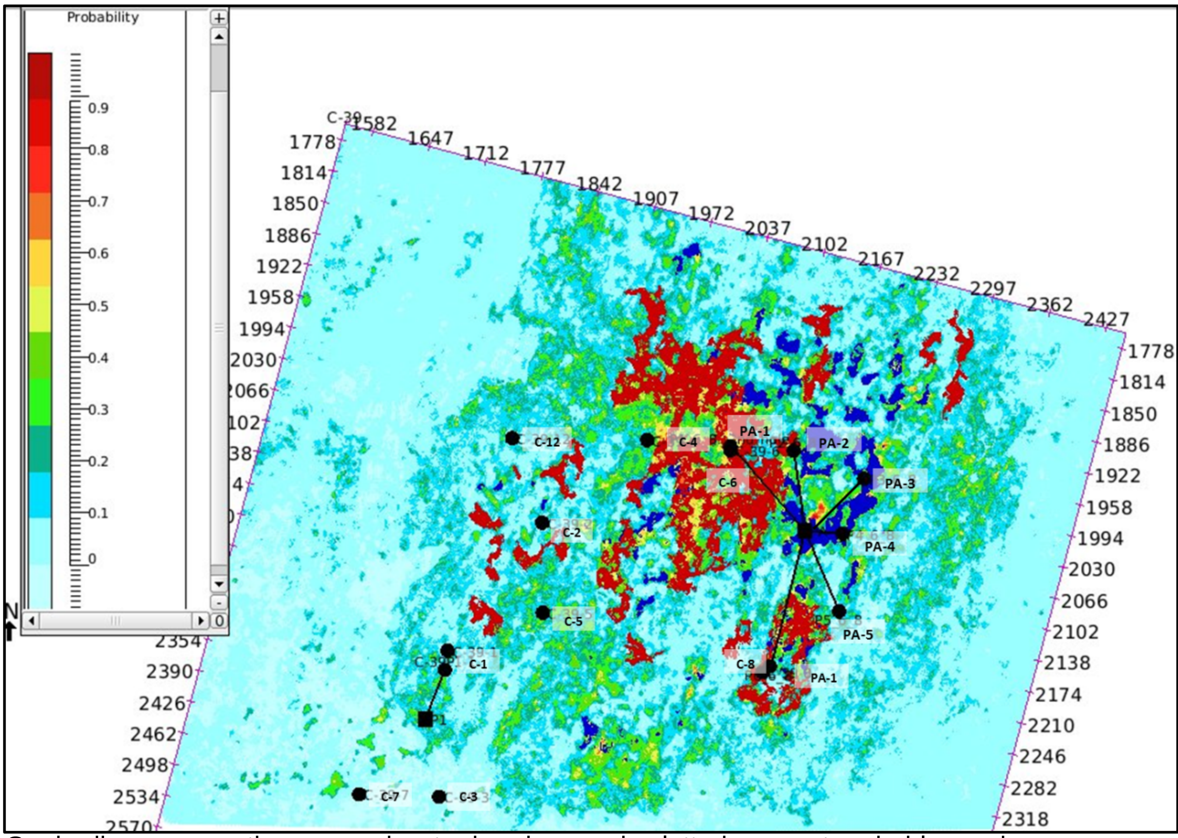


Fig. 10 Geobodies representing gas and water bearing sands plotted on most probable sand map.

Geobodies from these polygons coloured as red representing gas and blue representing water. Another development well C-PA3 (Fig. 10) which was drilled just above the Mahuva reservoir sand, because the rig was moved to drill another well as drilling was planned for a batch drilling. Incidentally this well was taken up for further drilling of about 30m to drill the planned section. The sand encountered in the well turned out to be water bearing. This led to a way forward in terms of a large area, represented by red colour geobody, to be exploited to the immediate west and south of the platform for further development.

Conclusion:

Thin and discrete gas sands of Mahuva Formation in C39 area though difficult to be captured could be understood using improved seismic imaging coupled with robust pre-stack inversion and using innovative technique utilising elastic property volumes generated through inversion.

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