Reservoir Characterization of Daman Sands in Tapti-Daman area using Vp/Vs,P-Impdeance, λρ and μρ analysis

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Keywords

Tapti-Daman, Daman Sands, Pre-Stack Inversion, Cross-Plots, Rock physics, Reservoir Characterization

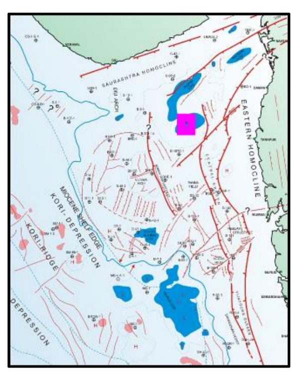
Summary

Daman Formation of Late Oligocene age in Tapti-Daman block of Western Offshore Basin, India has prolific gas reserves. In the current study area of B-12 /C-26 field, Daman Fm. is characterized by dominant well developed multi-stack sands (Sand 10 to 60 packs) with thin shale interbeds and occasional limestone. Within Daman formation, Sand-30 and Sand-40 are the main gas producers. Till now, sand geometries and HC distribution are characterized by RMS amplitude, extracted from seismic far angle stack data, which have been found to be HC bearing in more than 80% of the drilled wells. However, for further de-risking and improved characterization of reservoir sands, rock physics analysis of individual pay sands and Pre-stack seismic inversion have been carried out. Horizon guided attributes maps viz. Minimum Vp/Vs and Minimum Lambda-Rho have been generated for the individual pay sands; which corroborates with HC distribution in all the drilled wells. The generated attribute maps further provides locales for exploration of Daman Sands (Sand-30 & Sand-40) with very higher degree of certainty.

Introduction

Tapti-Daman block covers an area of about 27,000 sq. km. in the north-eastern part of Western Offshore Basin; situated at the west coast of India. It represents the transition stage between pure clastic Cambay Basin situated in the North and near-pure carbonate basin of Mumbai offshore in the South (Fig.1). Thus, mixed siliciclastic-carbonate system generally prevails in the area. In the study area of B-12/C-26 field, Daman Formation of Late Oligocene age is characterized by dominant well developed multi-stack sands (Sand 10 to 60 packs) with thin shale interbeds and occasional limestone; which were deposited in the form of tide dominated deltas (Fig.2). The micro environments are distributary / tidal channels, tidal bars and tidal flats. It is affected the most by Miocene inversion tectonics, which resulted in numerous traps of 4/3 way closures and up dip shale out traps. The availability of good porous sands of the order of 18 to 30 % and variety of traps make the Daman Play as the most important play with very high HC potential.

The seismic attributes such as RMS amplitude, extracted from seismic far angle stack data for the Sands-30 and 40 packs, clearly brings out, a number of channels and associated facies geometry in the study area, which have been found to be HC bearing in more than 80% of the drilled wells. However, to increase the probability of success, of striking new gas reserves; gas sands are characterized by rock physics analysis of individual pay sands, through Cross-Plots studies of *"Vp/Vs v P-Impedance"* & *"Lambda-Rho v Mu-Rho"*. Pre-stack seismic inversion is carried out and horizon guided attributes maps viz. Minimum Vp/Vs and Minimum Lambda-Rho are generated for the pay sands showing HC distribution. The drilled Gas wells and Dry wells with their ranges of Vp/Vs and Lambda-Rho validate the attribute maps for the presence/absence of Gas in the study area. With the combined use of Structure, RMS attribute and Pre-Stack Inversion attributes maps, additional areas for exploring Daman Gas sands (Sand-30 & Sand-40) have been established with reduced risks.



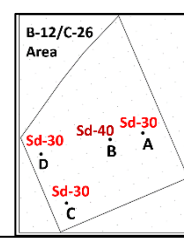


Fig.1 Tectonic Map of Western Offshore Basin showing study area.

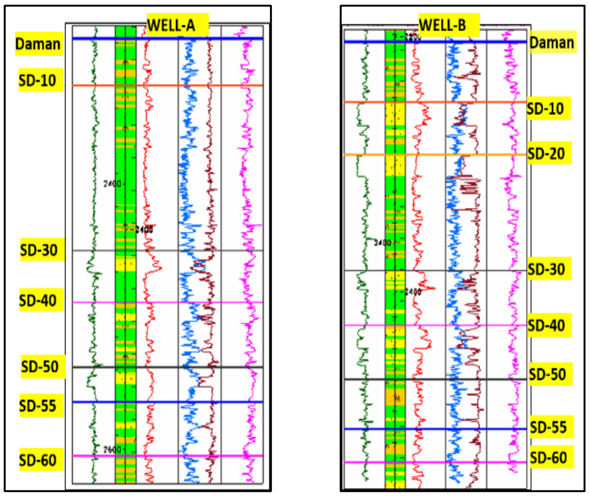


Fig. 2 Log motifs of wells A and B

Theory

Compressional P-wave is helpful in identifying pore fluids and lithology whereas Shear S-wave can be used for identifying minerals. Vp and Vs in terms of Lame's parameters λ (Lambda) and μ (Mu) are given by

$$V^2p = \frac{\lambda+2\mu}{\rho} \qquad V^2s = \mu/\rho$$

The λ term, or incompressibility, is sensitive to pore fluid, whereas the μ term, or rigidity, is sensitive to the rock matrix. As P-wave velocity decreases drastically and S-wave velocity increases marginally, with increase in gas saturation in a reservoir, the ratio of Vp/Vs can be used for characterizing gas sands. The ratio of Vp/Vs decreases with increasing gas saturation. By cross-plotting Vp/Vs against P-Impedance, gas saturated sands can be distinguished from non-reservoir rocks and water bearing sands (Odegaard et al. 2004) as shown in Fig.3.

An improved identification of reservoir zone is possible by the enhanced sensitivity to pore fluids from pure compressibility, as well as lithologic variations represented by fundamental changes in rigidity, incompressibility, and density parameters as opposed to mixed parameters of seismic velocities. (Goodway et al.1997).

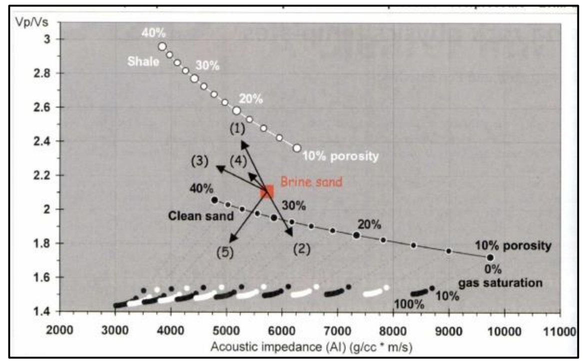


Fig.3 A Rock Physics Template for Vp/Vs v AI cross-plot. The (5) black arrows indicate increase in Gas Saturation. (From Odegaard et al. 2004)

$$V^2p = \frac{\lambda+2\mu}{\rho} \qquad V^2s = \mu/\rho$$

$$V^2p\rho^2 = \lambda\rho + 2\mu\rho \qquad V^2s\rho^2 = \mu\rho$$

$$V^2p\rho^2 - 2\mu\rho = \lambda\rho \qquad \boldsymbol{\mu\rho = Z^2s}$$

$$\boldsymbol{\lambda\rho = Z^2p - 2Z^2s}$$

Cross-plotting λρ and μρ, provides improved petrophysical discrimination of rock properties over conventional Vp, Vs analysis (Goodway et al. 1997) as shown in Fig4.

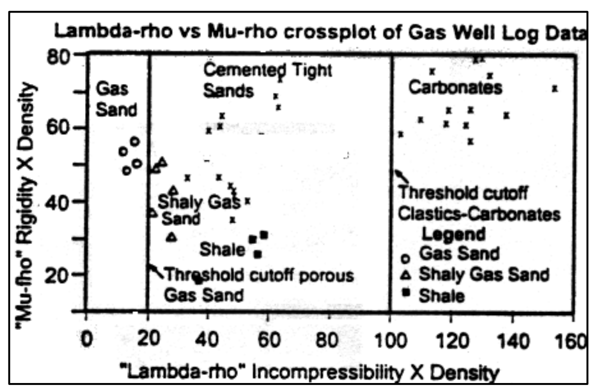


Fig4. Cross-Plot of λρ and μρ showing separation of Gas Sands with low λρ values. (From Goodway et al. 1997)

Pre Stack Seismic Inversion

The Pre-stack seismic inversion of B-12/C-26 field with an area of around 500 sq. km has been carried out for reservoir characterization of sands, using 4 wells

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viz. A, B, C and D; having P-Wave, S-wave and Density logs. The pre-stack time migrated gathers are conditioned and reprocessed but gathers could be flattened to the maximum angle of 30 degrees. Apart from P-Impedance, S-Impedance, Vp/Vs ratio volumes, Lambda-Rho and Mu-Rho volumes are also generated. As the PSTM seismic data has a frequency bandwidth of about 5-70HZ @ -12dB for Oligocene section, P-Impedance and Vp/Vs logs are High-cut filtered @70Hz and overlaid on P-Impedance and Vp/Vs logs are extracted from Inverted volumes to QC the inverted volumes (Fig. 5).

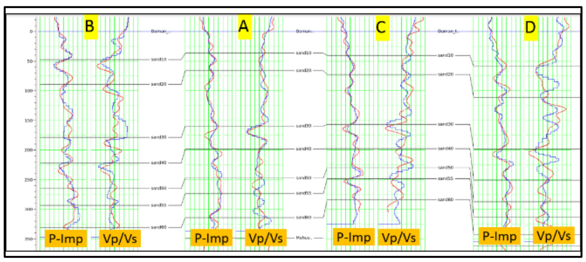

Fig.5 Inversion QC of wells. Red curves are well logs high cut filtered at 70Hz. Blue curves are traces derived from inverted volumes.

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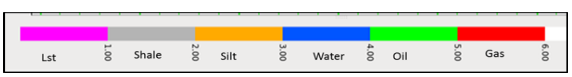
The lithologs with hydrocarbon and water are interpreted for the wells using Well logs and Well testing; and the cross-plots are colored with these lithologs, so as to easily discriminate the fluid types and lithologies.



Sand-30 is characterized using wells A, C and D. In well A, gas bearing Sand-30 exhibit low P-Impedance values (5500-7500 g/cc*m/s) which separates it from water bearing sands; and low Vp/Vs values (1.54-1.88) which separates the gas sands from non-reservoir rocks and water-bearing sands (>1.8). However, upper ranges of Gas Vp/Vs have a minor overlap with the Vp/Vs ranges of water bearing sands. To further substantiate this characterization, Lambda-Rho v Mu-Rho plots are generated at log scale and at seismic bandwidth i.e. Logs High-cut filtered @70Hz and the results are compared with Vp/Vs and Impedance logs extracted from Pre-Stack Inversion Results. In the above mentioned three wells, gas bearing Sand-30 clearly stands out from water bearing sands and non-reservoir rocks having low values of Lambda-Rho (<23).The following cross-plots corresponds to well A (Fig. 6-11).

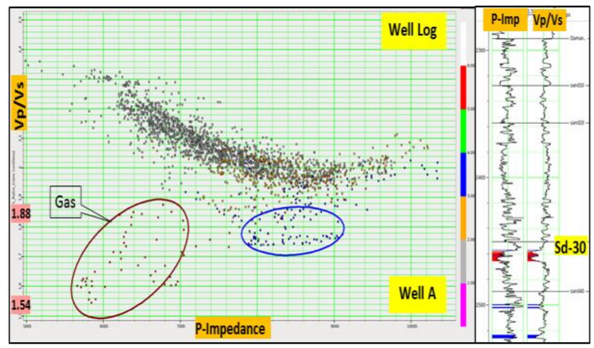


Fig.6 Cross-plot of Vp/Vs v P-Impedance at Log scale.

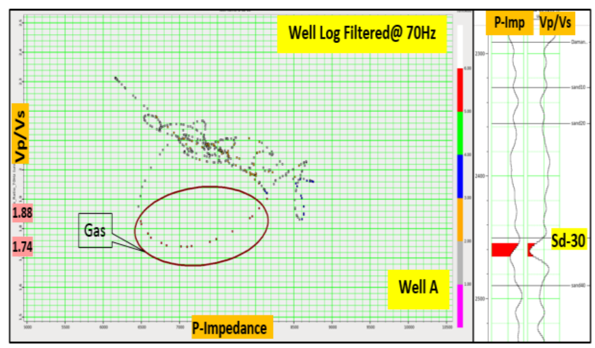


Fig.7 Cross-plot of Vp/Vs v P-Impedance filtered @ 70Hz

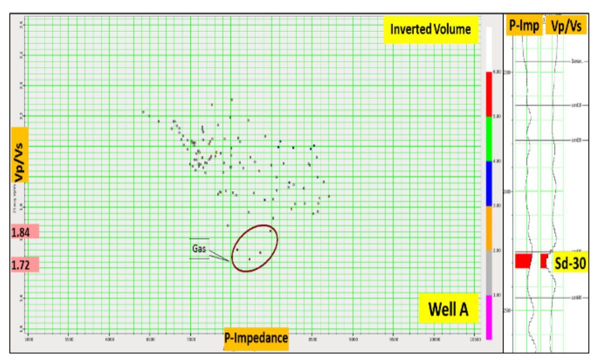


Fig.8 Cross-plot of Vp/Vs v P-Impedance from Inversion volumes

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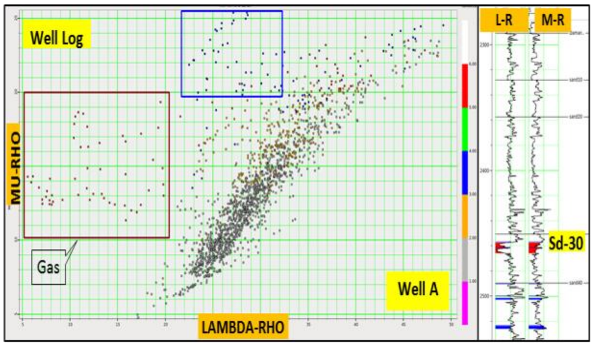

Fig.9 Cross-plot of λρ v μρ at Log scale

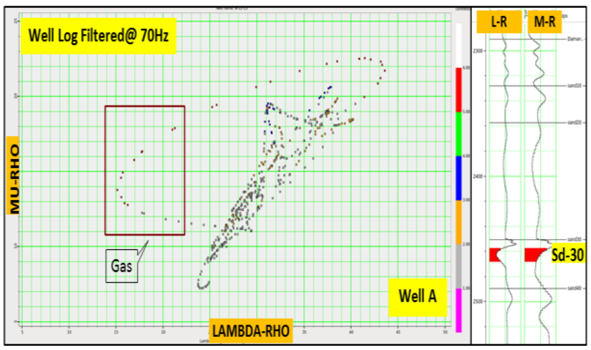

Fig.10 Cross-plot of λρ v μρ filtered @70 Hz

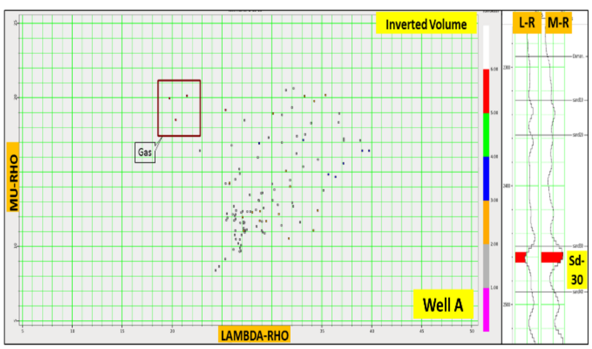

Fig.11 Cross-plot of λρ v μρ from Inversion Volumes

WELL	MINIMUM Vp/VS	MINIMUM P-IMPEDANCE m/s*g/cc	MINIMUM LAMBDA-RHO GPa*g/cc
D	1.72	6929	17.22
C	1.69	6560	14.70
A	1.74	7320	18.67

The above mentioned values are derived from pre-stack attributes maps of Sand-30 which are in conformance with the Cross-Plot analysis results (Fig. 12-13).

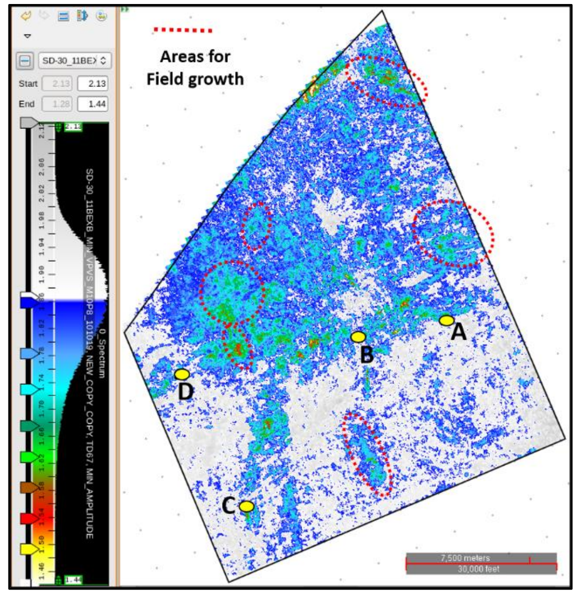

Fig.12 Minimum Vp/Vs (M10P8) corresponding to Sd-30

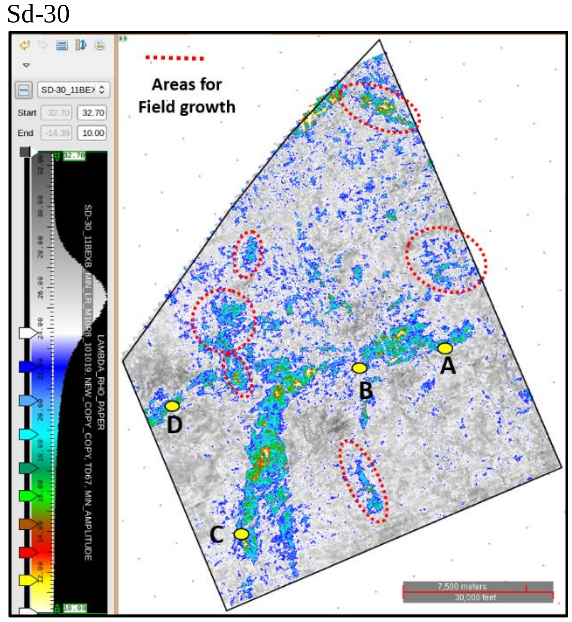

Fig.13 Minimum Lambda-Rho (M10P8) corresponding to Sd-30

For characterization of **Sand-40**, well B is used. In the cross-plot (Fig.14-19) of Vp/Vs and P-impedance, low Vp/Vs values (1.5-1.8) of gas bearing sand separates them from water-bearing sands (>1.8) and non-reservoir rocks; which is further corroborated by the low Lambda-Rho values (< 20) of gas bearing Sand-40 compared to water bearing sands and non-reservoir rocks in the cross-plot of Lambda-Rho v Mu-Rho.

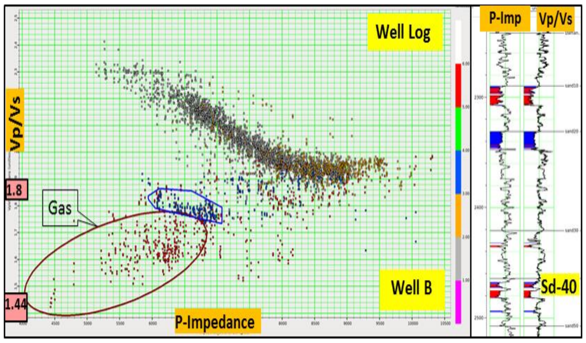

Fig.14 Cross-plot of Vp/Vs v P-Impedance at Log scale

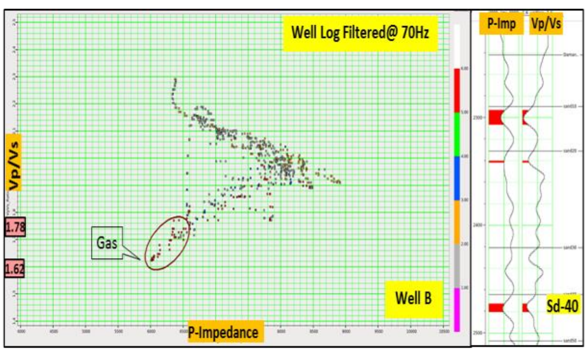

Fig.15 Cross-plot of Vp/Vs v P-Impedance filtered @ 70Hz

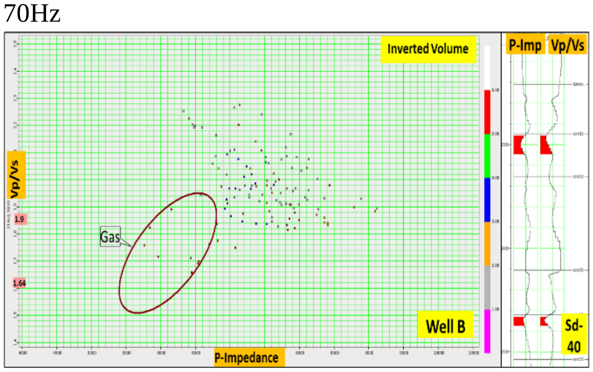

Fig.16 Cross-plot of Vp/Vs v P-Impedance from Inversion volumes

The following table has attribute derived values from pre-stack inversion volumes for Sand-40 which are in conformance with the Cross-Plot analysis results (Fig. 20-21).

WELL	MINIMUM Vp/VS	MINIMUM P-IMPEDANCE m/s*g/cc	MINIMUM LAMBDA-RHO GPa*g/cc
B	1.66	6416	11.22

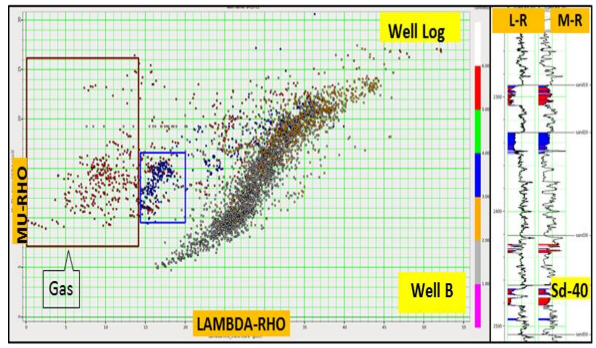

Fig.17 Cross-plot of λρ v μρ at Log scale

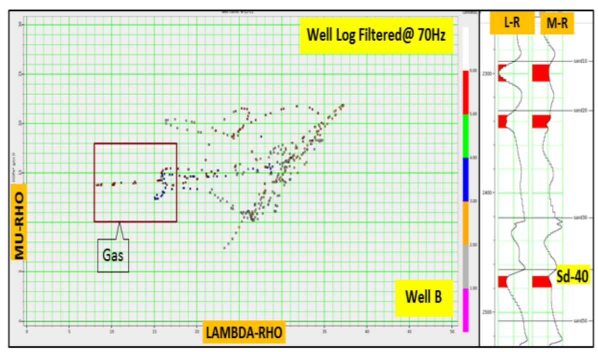

Fig.18 Cross-plot of λρ v μρ filtered @ 70Hz

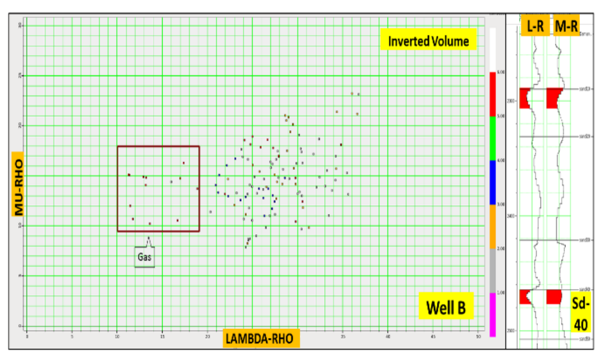

Fig.19 Cross-plot of λρ v μρ from Inversion volumes

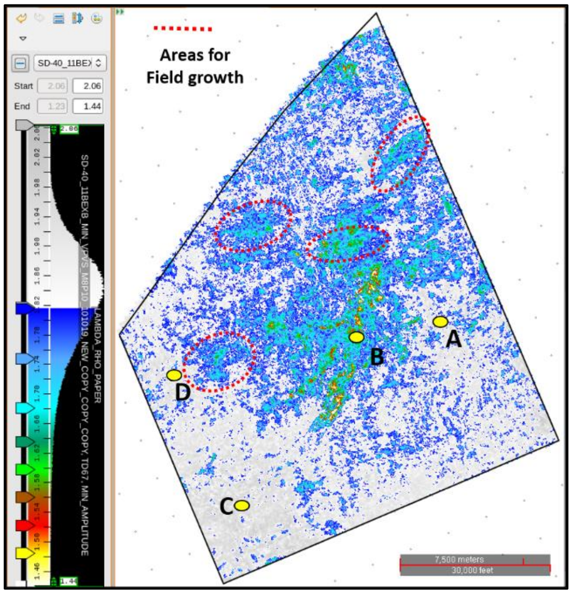

Fig.20 Minimum Vp/Vs (M8P10) corresponding to Sd-40

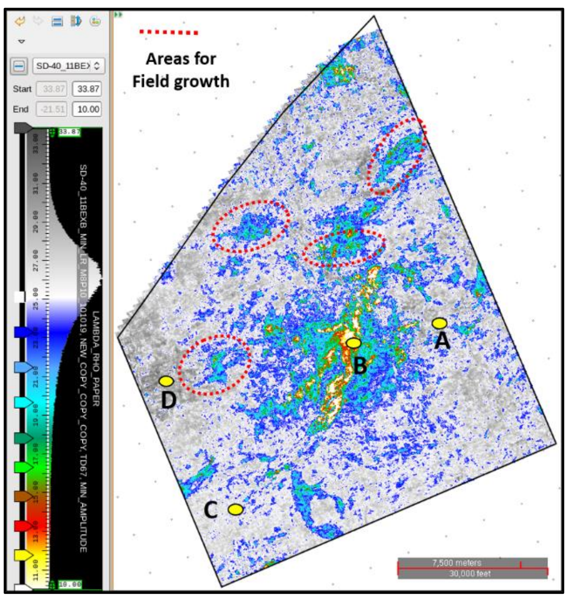

Fig.21 Minimum Lambda-Rho (M8P10) corresponding to Sd-40

Conclusions

The RMS amplitude extracted from Far angle stack data has clearly delineated the Daman channel sands depositional patterns; which also have been proved to be HC bearing in most of the wells. However, to further minimize the risks, gas sands are petrophysically characterized using *Vp/Vs v P-Impedance* and *Lambda-Rho v Mu-Rho* cross-plots. Attributes maps using Pre-Stack Inversion volumes, with corresponding cut-off values derived from the cross-plots are prepared for the individual sands. The resultant maps which satisfies the wet/dry wells, provides additional areas for exploration in the vicinity of developed field of B-12/C-26 for field growth.

References

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