An approach for sweet spot identification using post-stack inversion to aid infill well location optimization, Raag Oil Field

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Abstract

Predicting reservoir properties, such as Vshale distribution away from wells, has always been a fundamental requisite for appropriate infill well planning, and development of the Fields. Delineating reservoir properties from seismic data poses a major challenge due to its bandwidth limitation. However, the seismic inversion converts the seismic interface properties into quantifiable elastic layer properties and removes the wavelet effects. A post-stack seismic inversion project was carried out in Raageshwari Oil Field with an objective of deriving acoustic impedance property. Next, using the rock physics analysis, the petrophysical properties have been estimated using acoustic property. The predicted petrophysical property volumes helped us in identification of sweet spots to optimize placement of infill well and to ensure enhanced field productivity.

Introduction

The Barmer Basin is a narrow NNW-SSE oriented rift basin that has undergone various episodes of rifting. The Raageshwari field is located on the Central Basin High (CBH), which is a structural high feature situated centrally in the Barmer Basin (Figure 1). The northern and the shallowest structural culmination in Thumbli level include the Raageshwari Oil Field. Below Raageshwari Oil Field, there is another field, the Raageshwari Deep Gas field is present. The Raageshwari structure is essentially an easterly dipping tilted fault block and develops horst block morphology due to an additional fault on the eastern side of the structure. The wells penetration in the area includes, both shallow Raageshwari oil wells and the Raageshwari Deep gas wells, which have encountered the entire stratigraphy of the Barmer Basin. Successful hydrocarbon discoveries have been made in, Upper Thumbli, Basal Thumbli, Fatehgarh and Pre-rift formations.

Raageshwari Oil development plan is focused on the Upper Thumbli reservoir units of Thumbli Formation. The Thumbli Formation has been subdivided into the lowermost Basal Thumbli, Middle Thumbli and Upper Thumbli. This subdivision of the Thumbli Formation is based primarily on well log data, lithological description of drill cuttings and gas chromatographic data. Based on the regional understanding and the regional depositional model, it is interpreted that the Basal Thumbli (BT) is deposited in a lacustrine environment, Middle Thumbli (MT) in a deep lake setting and Upper Thumbli (UT) in shallow lake margin environment with strong influence of fluvial channel systems. The Upper Thumbli is further subdivided into 5 sub-units, UT5 to UT1, wherein UT1 is the deepest unit and UT5 is the shallowest. UT4, UT3 and UT1 units are hydrocarbon bearing whereas UT2 and UT5 are non-reservoir mudstones. Among the hydrocarbon reservoir units, UT1 has very low NTG. Hence, the target reservoir level for the study is UT4 and UT3 zone having better NTG compare to UT1.

This paper illustrates the workflow implemented in Raageshwari Oil Field in identification of sweet spots in reservoir, optimization of well placement to ensure the enhanced field productivity. The workflow includes the following steps:

1) Well based rock physics feasibility study,
2) Post-stack inversion for acoustic impedance,
3) Estimation of petrophysical properties from acoustic impedance
4) Discriminating lithology and identification of sweet spot in reservoir, and
5) Optimizing well placement and enhance productivity.

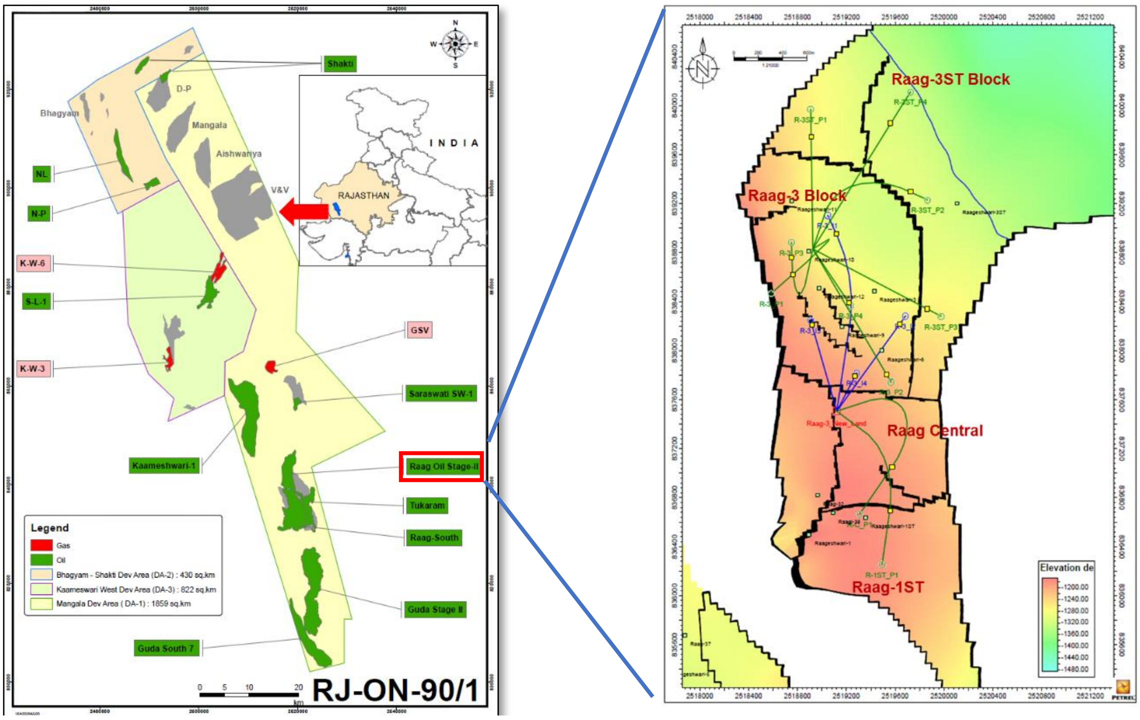

Figure-1. Location map of Barmer Basin and Raageshwari Oil Field

1. Well based rock physics feasibility study

Rock-physics analysis has been done at reservoir level to understand the relationship between petrophysical property and acoustic property. Raag Oil field wells has been used to study the relationship and check the feasibility of Inversion. From the cross-plot analysis of VP/VS and P-Impedance, it has been observed that P-impedance is a clear lithology discriminator (Figure 2). Additionally, there is a good correlation between Vshale log and Acoustic Impedance giving further confidence to use seismic data to predict reservoir property (Figure-3). As seen in figures below, the feasibility study has established the link between elastic properties and petrophysical properties and lithology discrimination can be done using acoustic impedance.

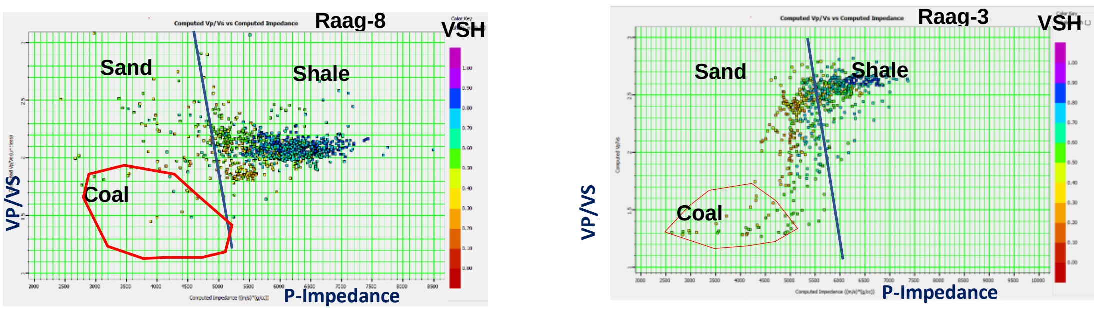

Figure-2. Cross-plot of VP/VS and P-impedance in Raag-3 and Raag-8 well respectively. They show lithology discrimination based on P-impedance

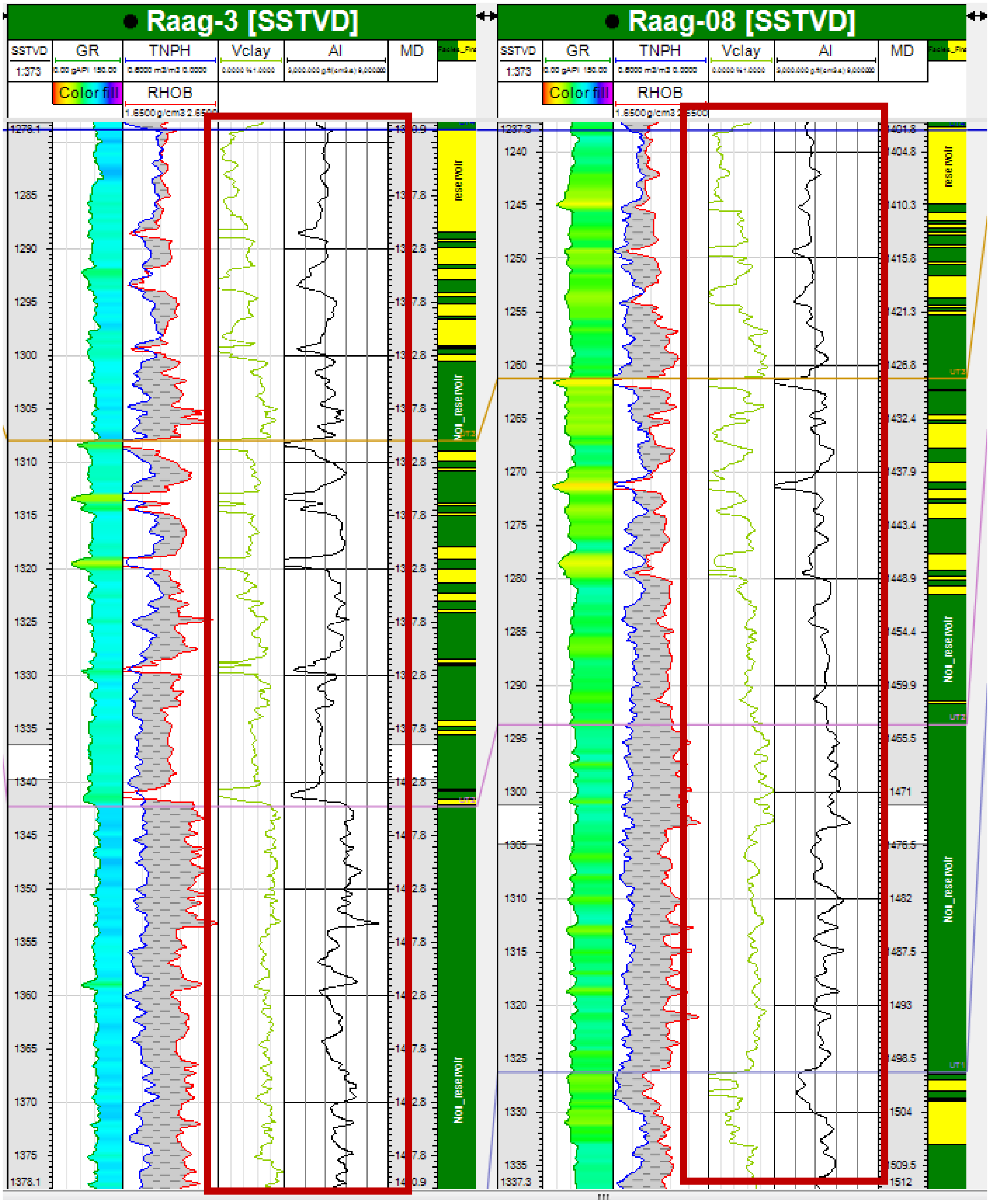

Figure-3. Well logs of Raag-3 and Raag-8 well respectively showing good trend between Vshale log and Acoustic Impedance log.

2. Post-stack inversion Results and Discussion

Following the successful feasibility study, a seismic deterministic inversion was performed to invert 3D seismic data into P-impedance volume. Pre-stack depth migrated seismic volume has been used for inversion. The data quality was good with high signal to noise ratio and has the dominant frequency of around 30 Hz. Synthetic seismograms were prepared and seismic to well ties were done and ensured that near zero phase seismic data was input for the deterministic inversion. Next, a low frequency model was generated using the available wells and interpreted horizons. Finally, a model-based inversion was run in Hampson-Russell software. Post stack inverted acoustic impedance was then QCed and the volume was used for better delineation of lithology at reservoir level.

In general, Sands are low acoustic impedance, acoustically softer compared to shales. Sands are represented by hot color in the below figures. There has been excellent match between the inverted and measured P-impedances at well location Raag-3 (Figure 4). Validation of result has been done using blind wells (Figure 5).

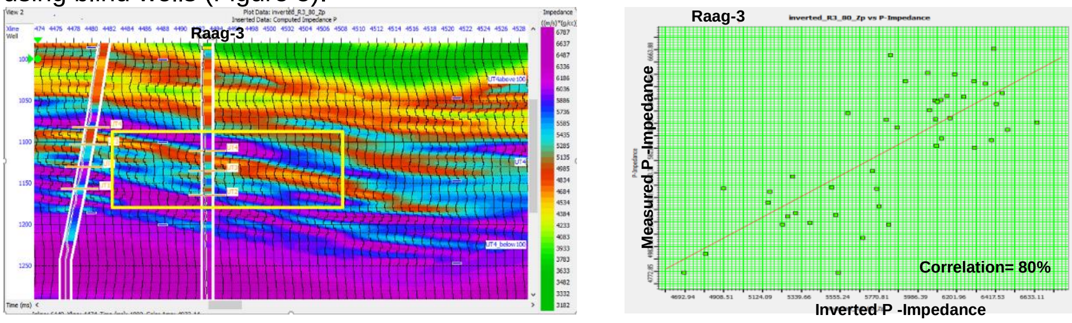

Figure-4. QC of the inversion results at the well location Raag-3, Notice the excellent match between the inverted and measured P-impedances at reservoir level

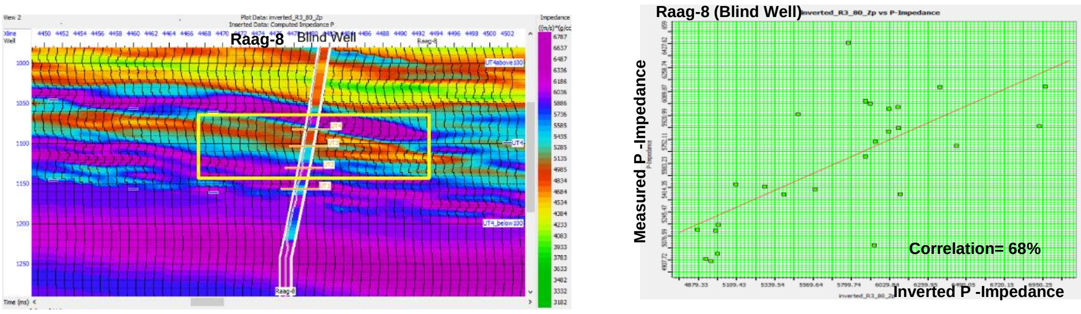

Figure-5. Validation by blind well test, Notice the good match at reservoir level

3. Estimation of petrophysical properties from acoustic impedance

Petro-elastic model is a process that connects petrophysical property to the elastic property. This method has been used to estimate petrophysical property (Vshale) from elastic property of reservoir rock (Acoustic Impedance) through a transform equation obtained from the cross-plot of Vshale and Acoustic Impedance (Figure-6).

4. Sweet Spot Identification

There is a good correlation between Vshale log and acoustic impedance log (Figure-3). Hence, transform equation from the cross-plot of Vshale and acoustic impedance has been used to generate Vshale Volume from the inverted seismic AI volume (Figure-6). There has been good correlation between transformed Vshale and measured Vshale (Figure-7). Validation of result has been done using blind wells (Figure-8). Average magnitude of Vshale extracted at reservoir level UT4-UT3 zone correlates well with reservoir properties at well locations (Figure-9). The highest correlation of 79% observed between Vshale and Net Sand thickness (Figure-10).

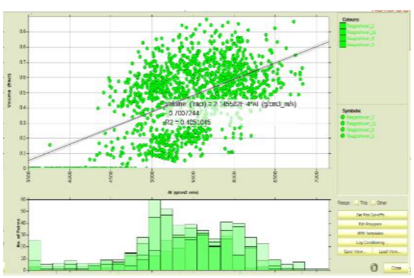

Figure-6. Cross-plot of Vshale and Acoustic Impedance

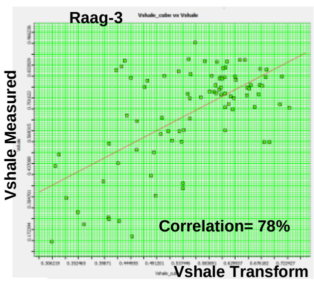

Figure-7. QC of the Vshale transformation results at the well location Raag-3

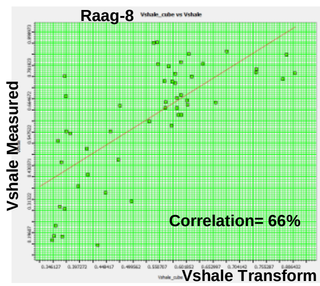

Figure-8. Validation of transformed Vshale at blind well.

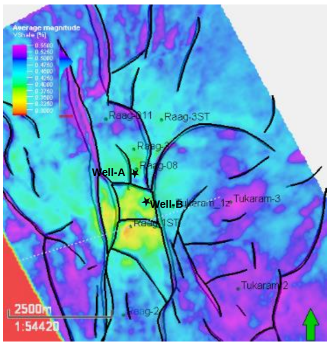

Figure-9. Average magnitude map of Vshale extracted at reservoir level UT4-UT3 zone

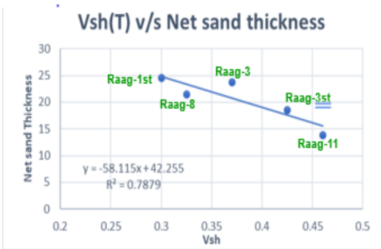

Figure-10. Cross-plot of Vshale and Net Sand Thickness

Drilling Campaign Wells	VSH Transformed	Net Sand thickness Predicted	Net Sand thickness Actual
Well A	0.37	20.7	22
Well B	0.32	23.6	21

Figure-11. Comparing the results at drilled wells of the drilling campaign

5. Optimizing well placement and enhance productivity

The new wells placement in the drilling campaign has been optimized in such a manner so that it targets sweet spot from the Vshale volume at the well location (Figure-11). In Figure-9, bright amplitude indicates good sand zone, having high net sand thickness and low Vshale. The well drilled in sweet spot results in high Net sand thickness reservoir and hence having enhanced productivity.

Conclusions

In this study, Post stack inversion added significant value in delineating thin sand which is below seismic resolution. Due to the good correlation between the Vshale and Net sand thickness, results being used as an effective development tool, reducing subsurface uncertainties for reservoir characterization, maximizing the reservoir penetration, and thus optimizing the well locations during field development campaign. Additionally, the results will be used for the upcoming drilling campaign of Raag Oil Field and for property distribution in the reservoir modelling for field development.

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References

Avseth, P., Mukerji, T. and Mavko, G., 2005. Quantitative Seismic Interpretation, Cambridge University Press. Mavko, G., Mukerji, T., and Dvorkin, J. 1998. The Handbook of Rock Physics, Cambridge University Press.

Malkani, A., Somasundaram, S., Ravichandran, V., Mukherjee, S., Hansen, P. and Mishra, S., 2014, June. P-impedance Inversion-A Fit for Purpose Technique for Reservoir Characterization, Mangala Field, India. In *76th EAGE Conference and Exhibition 2014* (Vol. 2014, No. 1, pp. 1-5). European Association of Geoscientists & Engineers.

Somasundaram, S., Mund, B., Soni, R. and Sharda, R., 2017. Seismic attribute analysis for fracture detection and porosity prediction: A case study from tight volcanic reservoirs, Barmer Basin, India. *The Leading Edge*, *36*(11), pp.947b1-947b7.