



## Enhancing the Reservoir Characterization Experience through Post Migration Reprocessed (PMR) Data – A case study from Cauvery Basin

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### Keywords

PMR, Reservoir Characterization, EEI, LR

### Summary

Reservoir characterization is one of the essential and challenging part of any field development as it is needed to formulate the optimum well placement strategy so that returns can be maximized with prudent investments. Seismic Inversion plays a very crucial part in reservoir characterization, which is highly dependent on input seismic data quality. In general, conventional processing attempts to preserve the amplitude and AVO behavior, but for carrying out robust simultaneous inversion (SI) and Extended Elastic Impedance (EEI) the data quality is often less than appropriate, as these techniques require specific target oriented processing. Now a days it's a common practice to have an additional processing workflow known as Post Migration Reprocessing (PMR) for data quality enhancement targeting specific needs of AVO based reservoir characterization.

A comparative study of reservoir characterization based on legacy and PMR data shows a significant improvement in capturing the heterogeneity in a complex synrift reservoir. There is an improved match between well log properties and inverted properties from PMR compared to Legacy data, thus PMR can add significant value to seismic data and improve the reservoir property estimation through latest reservoir characterization techniques.

### Introduction

The study area of approximately 50 sq km lies offshore in Cauvery Basin, East coast of India. The area has single well penetration which encountered 145m thick gas reservoir in Early Cretaceous, Syn-rift section. The entrapment is envisaged to be structural in nature with simple container geometry, having high NTG sand reservoir.

The well was drilled at a water depth of 1767m. The top 15m of the reservoir zone is carbonaceous, tight

sandstone layer. The hydrocarbon interval below the tight layer was divided into two gas zones: Zone 1 and Zone 2. Zone 1 is high energy, conglomeratic to very coarse grained sandstone with predominantly calcite cementation. Zone 2 is mineralogically immature lithic fragment/plagioclase feldspar rich sandstone with zeolite cementation. Both the zones have porosities of the same order (9-10%) however the water saturation in Zone1 is less than 20% whereas it is about 50% in Zone2. The reservoir is in general poor with single digit mili-Darcy permeability. MDT pressure data indicates the two gas zones to be in communication.

Well data and seismic attribute variability over the reservoir indicate the presence of vertical as well as lateral reservoir heterogeneity. Multipronged approach was used to delineate Zone1 and Zone2 laterally and vertically, and to understand the reservoir heterogeneity. This started with simple colour inversion to more sophisticated simultaneous inversion to extended elastic impedance volume generation. Most of the property outputs indicated smooth layered reservoir with negligible vertical as well as lateral heterogeneity, and much smaller gross pay thickness than what was encountered at well. Subsequently Post Migration Reprocessing (PMR), to enhance the seismic data quality was implemented on the existing dataset.

Reservoir characterization on enhanced dataset has shown significant improvement in the definition of property models. The correlation at the well has improved considerably in terms of pay thickness as well as vertical property match. The revised, estimated property volumes are helping in building more confident geological models, constrained simulations and optimal appraisal well placement.

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### PMR Workflow

Post Migration Reprocessing (PMR) is an AVO friendly technique which stabilizes the intercept, gradient and stacked sections that play a significant role in carrying out any type of Pre-stack inversion to generate robust elastic property volumes for fluid and lithology discrimination.

PMR workflow consists of two parts:

- Pre-Stack Level –  
Main steps are de-noising, flattening of gathers, offset balancing and scaling. In pre stack level, removing residual multiples, linear noise, gather flattening, results in stable data with less jittery gradients and improved stand-out of signal.
- Post-Stack Level –  
After generation of AVO attributes, Structural consistent filtering (SCF) and gradient stabilization (STAVO) is done by decomposing the gradient into different frequency bands and then applying the filter in the individual frequency bands separately. This reduces the risk of over smoothing the data.

The basic steps for PMR workflow is shown as a flowchart below (Figure-1).

Post migration reprocessing (PMR) flow was applied to Pre-stack depth migrated legacy gathers, the stacked seismic, intercept and gradient sections through well inline from legacy and PMR data volumes are shown in Figure 2, which clearly show that in PMR data the image is less noisier and crisper compared to its legacy counterpart.

### Log analysis and identification of RC attribute

A detailed analysis of the log data has been carried out to find out most suitable acoustic/elastic property, which can be generated from seismic data volumes and used to identify reservoir/ HC bearing intervals away from well (Figure 3). The acoustic log analysis showed almost flat response below the tight calcitic sandstone layer, highlighted in grey in Figure 3. No differentiation was observed between gas and brine sands (Zone 2 shown in green and water zone with blue). Amongst the elastic log properties, the Lambda-Rho property was found to be more effective in capturing gas zone. The non-reservoir calcitic sandstone on top is characterized by very high LR,

whereas gas zone shows lowering of LR property, compared to the underlying water zone.

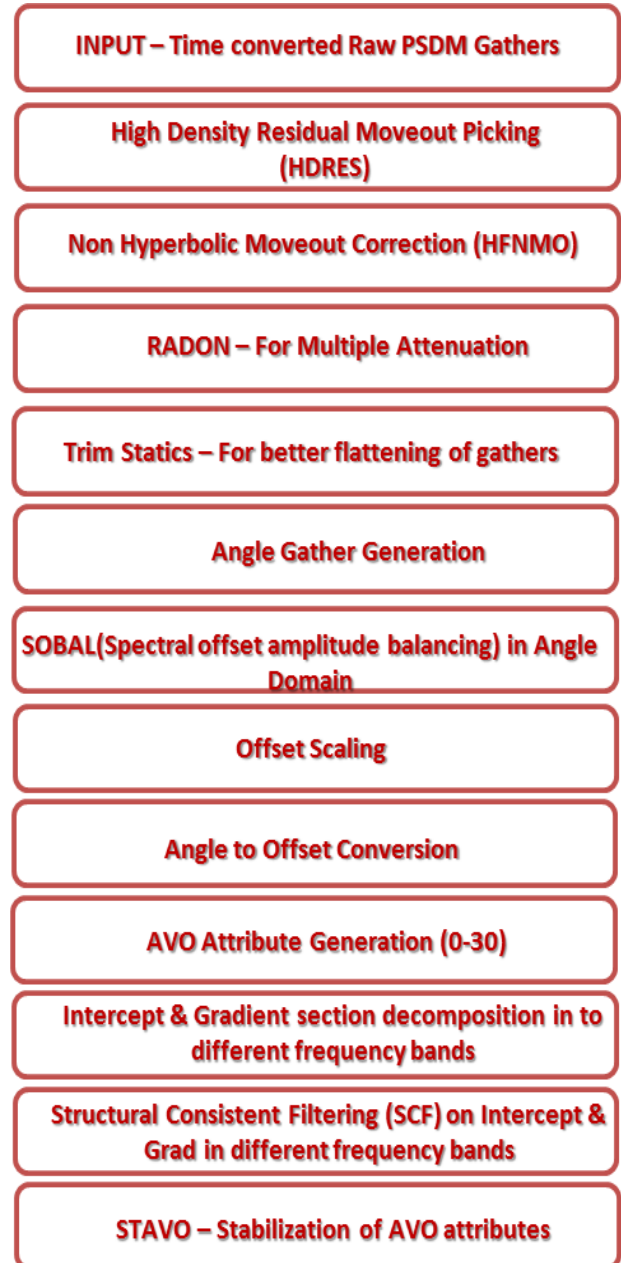


Figure 1: Flowchart for Post Migration Reprocessing (PMR) workflow.

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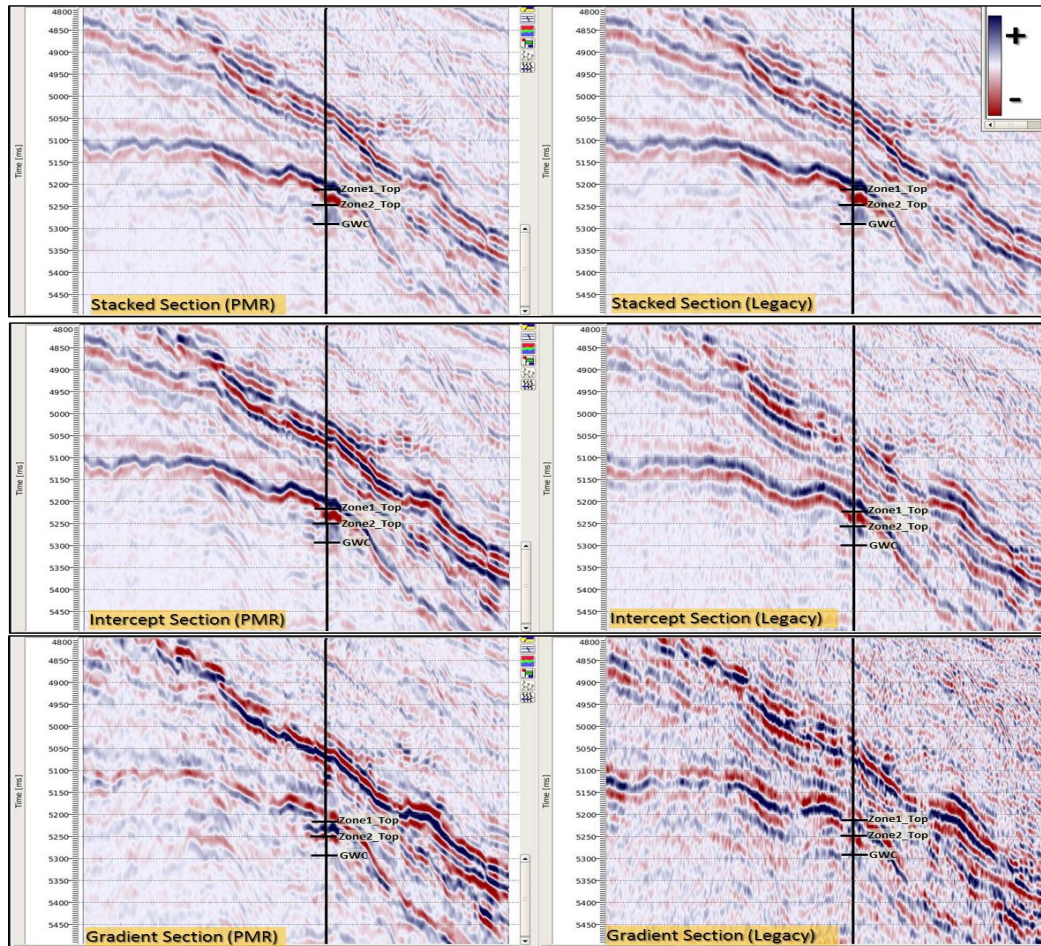


Figure 2: Sections showing comparison of Stacked seismic, Intercept and Gradient of Legacy with PMR data along well inline.

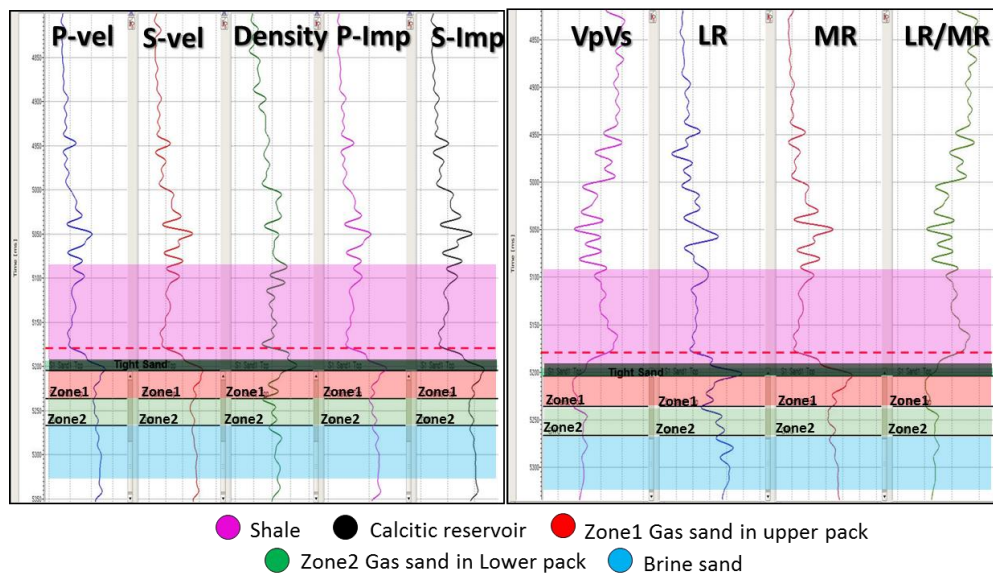


Figure 3: Well Log Analysis for drilled well

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## RC using Legacy Data

The simultaneous inversion was carried out using available three angle stacks from legacy seismic data and well data to generate LR volume. Standard workflow for simultaneous inversion was implemented after initial data conditioning. Prior to inversion, a high correlation between synthetic and seismic was achieved and stable wavelets were derived for each angle stacks.

The low frequency models (layered geologic models) using calibrated well and the seismic horizons were generated to provide reliable background property trends. These were used to invert the seismic data to generate elastic property volumes. The Lambda Rho volume was computed using results of simultaneous inversion. The band pass lambda-Rho property section through well, obtained from Legacy data is shown on left of Figure 6. The band-pass Lambda-Rho property captures the gas sand effectively as low LR attribute zone. The top calcitic non reservoir zone is well captured and seen as high LR property layer (yellow colour) in the section. The well has been overlain over the section and a reasonably good match is observed between well and seismically computed LR. However, the reservoir appears to be fairly homogeneous and lateral variations within reservoir are not fairly captured.

As an alternative approach for better reservoir definition and facies discrimination, Extended Elastic Impedance (EEI) inversion was attempted for this reservoir. Chi angle analysis indicated very high correlation coefficients of Extended Elastic Impedance (EEI) in the chi angle range of 20<sup>0</sup>-25<sup>0</sup> with effective porosity indicating that these elastic properties can be effectively used for porosity estimation over the reservoir (Figure 4).

Based on EEI analysis at the well, a transform was generated between EEI log and effective porosity (Figure 5) having a correlation coefficient of 74%, which was used for porosity computation. A section from the EEI porosity volume, overlain with well porosity is shown in Figure 7. Though well and seismic porosities show quite good match, the lower part of the reservoir porosity is not captured properly. Moreover, only about half of the 145m thick gas reservoir encountered at the well, is captured.

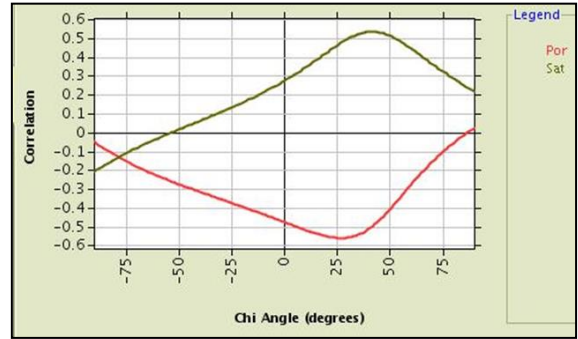


Figure 4:  $\chi$ -Angle analysis for Porosity & Saturation.

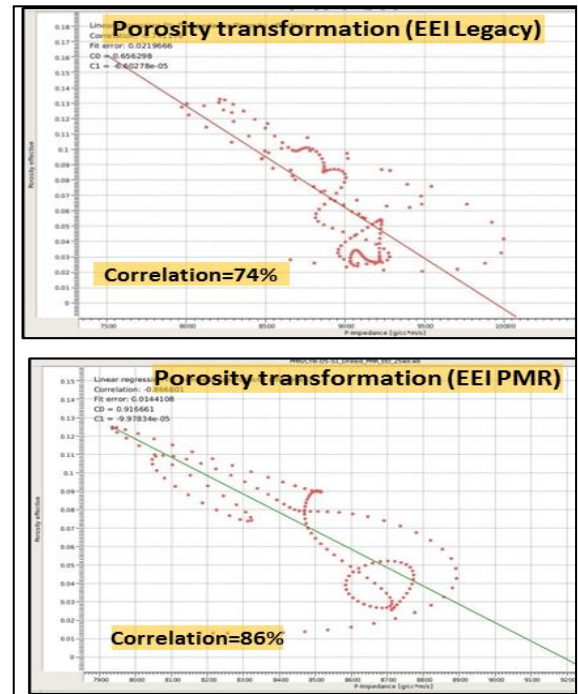


Figure 5: Porosity transform for EEI Legacy & PMR.

Another limitation is even though the seismic attribute indicate significant amplitude variations over the structure indicating lateral variability; the inverted property section did not capture the same.

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## RC using PMR Data

Post Migration Reprocessing (PMR) flow was applied to pre-stack depth migrated, legacy gathers to stabilize intercept, gradient and stacked sections to enhance the AVO/EEI applications of seismic data. A significant improvement in intercept and gradient can be seen in the sections (Figure 2). The complete reservoir characterization workflow was revisited using the PMR data set. Simultaneous inversion was carried out using five angle stacks from PMR seismic data and well data to generate LR volume (Figure 6). Extended Elastic volume was also generated using this new data set, which was inverted and porosity transform (Figure 5) with higher correlation than

legacy was used. Both these sections show significant improvement in capturing the actual thickness of reservoir zone encountered at the well, lateral variation of the porosity and also the internal layering pattern within the reservoir are better captured in these sections. The respective well properties have been overlain on the section (Figure 6 & 7). An improved match between computed and well properties is seen in case of PMR results. The porosity obtained from PMR data show significant improvement in the match with porosity well log compared to what could be achieved with legacy data.

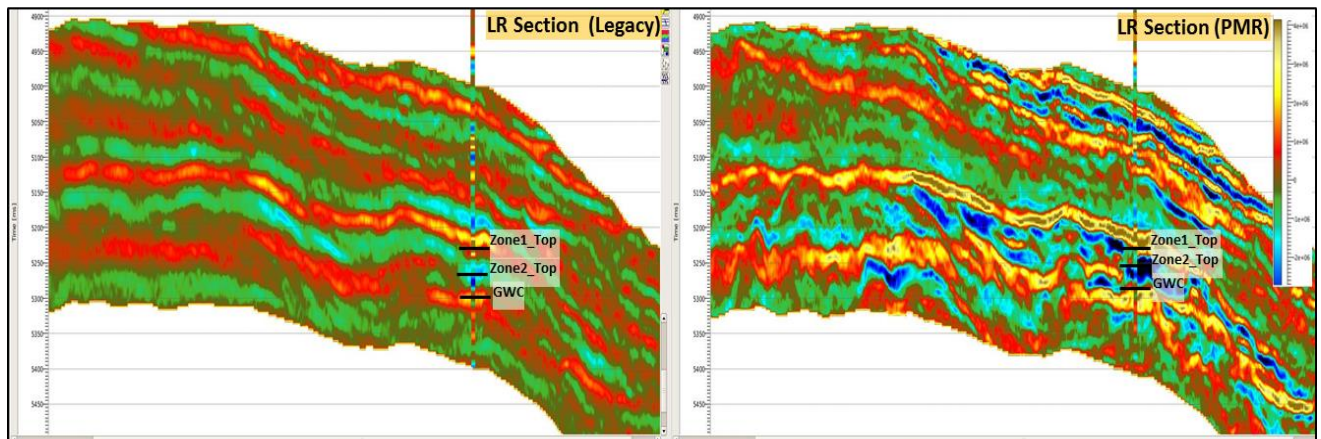


Figure 6: Bandpass LR section through well Inline for Legacy and PMR data

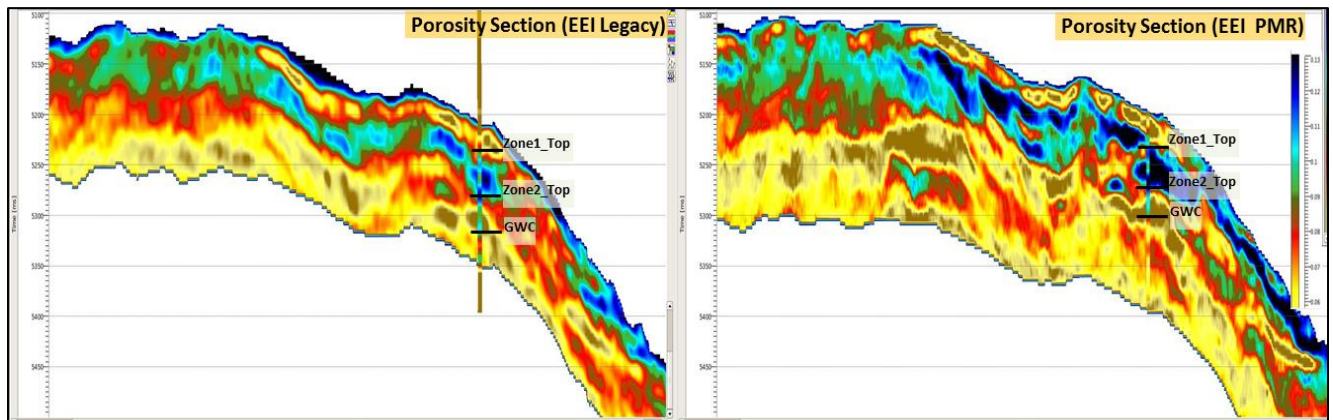


Figure 7: Porosity section through well Inline for Legacy and PMR data

## **Enhancing Reservoir Characterization Experience through Post Migration Reprocessed Data – A case study from Cauvery Basin**

### **Conclusions**

The seismic data contains imprint of reservoir variations, even in the absence of well resolved reflections.

Approaching the reservoir characterization through multiple techniques brings out the best one suited for a particular area.

The Post Migration Reprocessing (PMR) can add significant value to seismic data and improve the reservoir property estimation through latest reservoir characterization techniques even for the deep-seated complex syn-rift reservoir.

The results obtained from EEI inversion as well as simultaneous inversion of PMR data effectively capture entire gas zone.

The pseudo porosity log derived from PMR data shows significantly higher match with actual porosity log, specially in reservoir zone.

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