High Density High Resolution Seal Capacity and Pore Pressure Prediction from 3D Seismic Data

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SUMMARY

The estimated cost associated with geopressure problems can easily reach US$9 billion a year for the oil and gas industry. In recent years, with the increase of day rate for drilling rigs, semis and ships, it is more critical than ever to understand and quantify the formation pore pressure for assessing fluid migration, seal capacity, drilling risk, and well planning in order to high-grade the prospects, prevent drilling hazards and reduce cost in various exploration and production activities.

A methodology is developed to transform seismic interval velocity into a high density and high resolution pore pressure 3D volume and other pressure related attributes volumes including overburden, fracture limit, effective stress and equivalent mud weight. This article describes a rigorous workflow with real examples and highlights some key factors impacting the accuracy of velocity extraction and pore pressure prediction. In addition, integration with inversion and lithology can further reduce the uncertainty of pore pressure prediction and assist greatly the well planning from mud weight to drilling risk management, casing design and pipe purchase.

INTRODUCTION

There are many formulations and methodologies that use seismic attributes for pressure prediction. This work suggests how pore pressure can be accurately transformed from seismic interval velocity. It focuses on the areas of having the best prestack data, extracting the best seismic interval velocity, and creating an accurate rock model with well calibration for pore pressure prediction.

Through blind well tests and real case studies, it was proven that this methodology is practical and can provide critical information for prospect evaluation and well drilling.

METHODOLOGY

Prestack Data Conditioning and Velocity Analysis

The most important step of getting the best seismic velocity is to have the best data quality first. Here, prestack time migrated (PSTM) gathers have undergone a thorough processing flow to obtain the highest signal to noise ratio (SNR) by attenuating both coherent and random noises. After noises attenuated, the PSTM gathers were further enhanced, critically, by a high frequency imaging step for high resolution (HR) as described by Hamarbatan et al (2006). Then, an automatic 6^{th}-order velocity analysis based on Hake (1984) was applied to extract seismic interval velocity for every sample at every CMP location. This is an iterative loop specially for HR PSTM gathers. Figure 1a shows the progressive quality improvement of a PSTM gather after SNR and HR enhancements. Figure 1b shows the corresponding quality and resolution improvement of velocity analysis. The proper data conditioning has not only improved the confidence of velocity picking but also the vertical resolution of velocity picking.

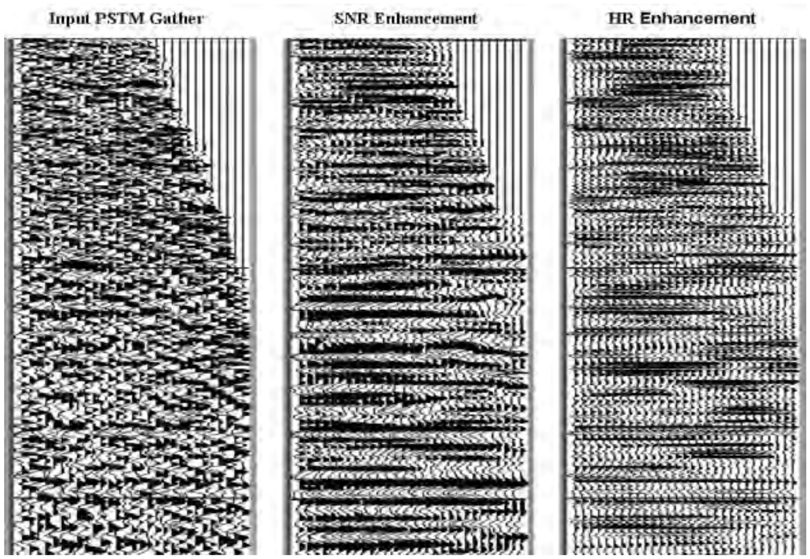

Figure 1a. Comparison of PSTM gathers after noise attenuation and resolution enhancement.

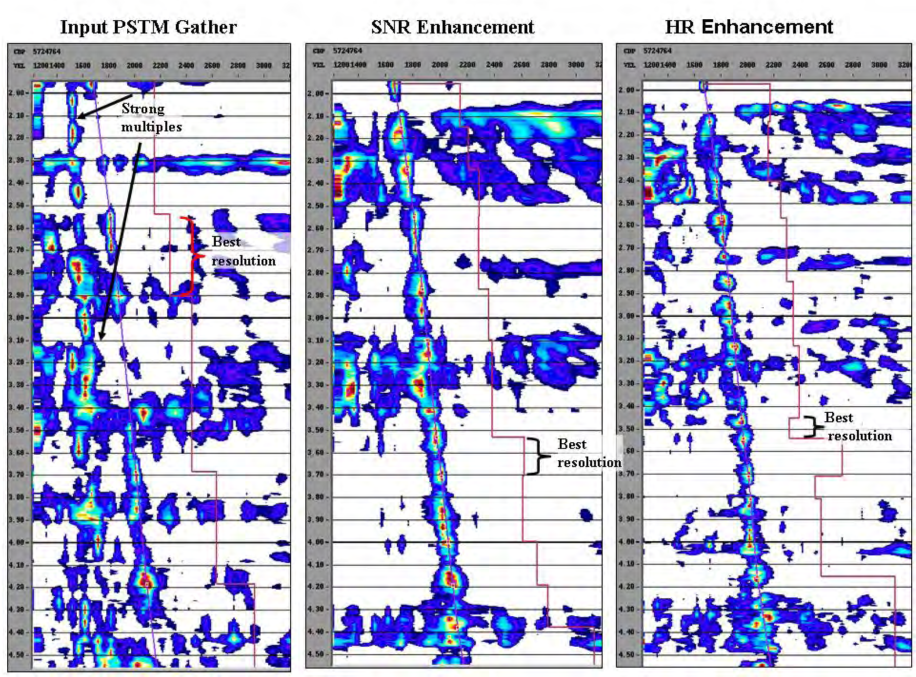

Figure 1b. Comparison of velocity analysis. The accuracy and the vertical resolution of velocity analysis was greatly improved after SNR and HR enhancement.

Rock Model for Pore Pressure Prediction

There are many causes of geopressure including but not limited to undercompaction, fluid expansion, lateral transfer and tectonic loading. A rock model combined of Dutta (1983, 2002) and Bowers (1995, 2002) was developed to transform seismic interval velocity to pore pressure taking into consideration of undercompaction, shale diagenesis and elasticity. Naturally, well and drilling information including logs, mud weight, temperature gradient, LOT, RFT, etc. was incorporated in the modeling. Figure 2 shows the rock model at a calibration well and the predicted mud weights with uncertainty fairway at the blind well location. The comparison between the real and the prediction is very favorable.

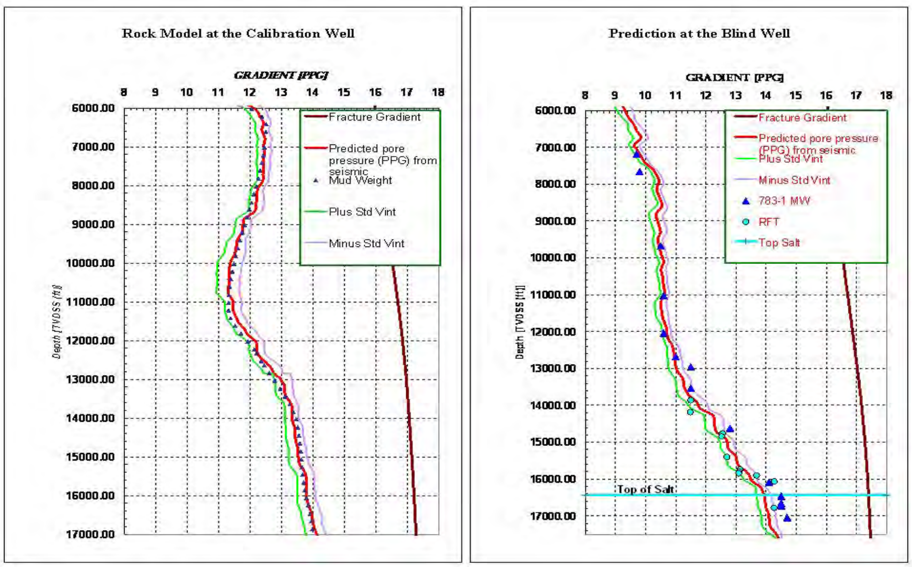

Figure 2. Rock model to the left at the calibration well and the prediction to the right at the blind well. The prediction matched quite well with the real mud weights and RFT results.

Results and Examples

One of the applications using pore pressure information is to evaluate the seal integrity of a trap and the seal capacity of a hydrocarbon column height. A study was conducted using this methodology to evaluate the fault seal integrity for an onshore gas play along the Gulf Coast of the United States. Figure 3 shows the predicted pore pressure at the prospective fault block and there was no pressure leakage on the other sides of the faults. The drilling found gas and proved that the prediction was successful.

Another application of pore pressure prediction is for drilling risk assessment and well planning. The operator drilled the deepwater well in the Gulf of Mexico using two nearby wells for pressure prediction and well planning. It turned out that the prediction was not accurate and the well needed to be abandoned due to unexpected abnormal pressure and running out of casing strings. Without knowing the well results, a study was conducted to predict the pressure using both normal resolution and high resolution seismic data.

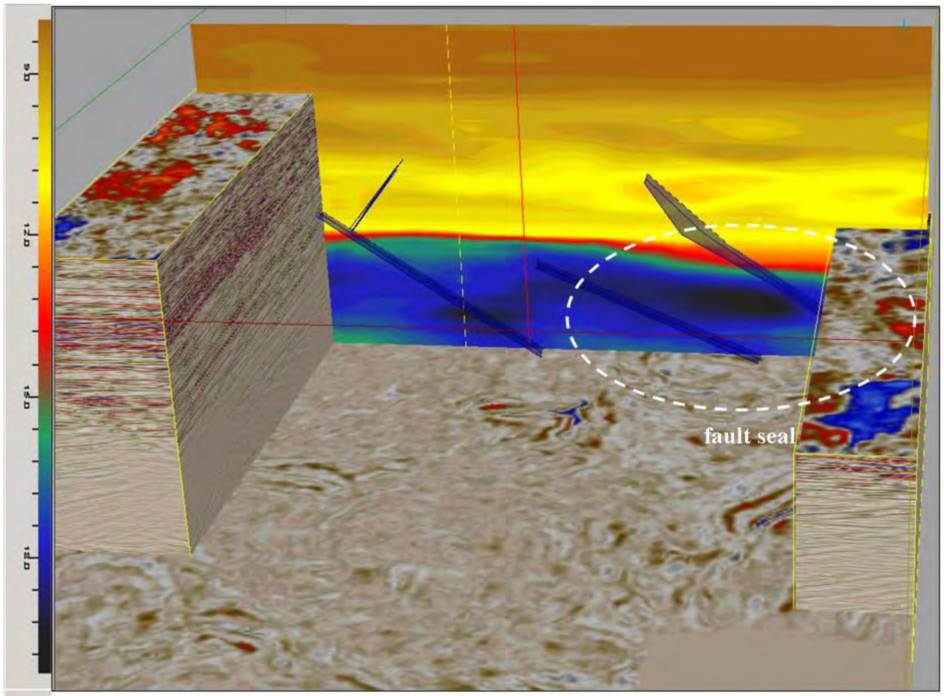

Figure 3. Pore pressure prediction for seal integrity evaluation. The prediction was confirmed by the well results for good top seal and good fault seal.

Furthermore, a poststack acoustic impedance (AI) inversion was carried out for lithology prediction. Figure 4 shows that higher resolution seismic gave more detailed pressure distribution that also coincided with the fingering of sands and shales near the prospect well in the AI section. This integrated approach provided a more confident result and a better understanding of 3D pressure cell distribution and centroid position for drilling risk.

CONCLUSIONS

Prestack data conditioning with high resolution enhancement is a must for high density high resolution high order velocity analysis and consequently for better pore pressure prediction with a right rock model is established. Integration with lithology can further narrow the uncertainly, understand better the pressure distribution, and reduce drilling hazard and cost.

ACKNOWLEDGEMENTS

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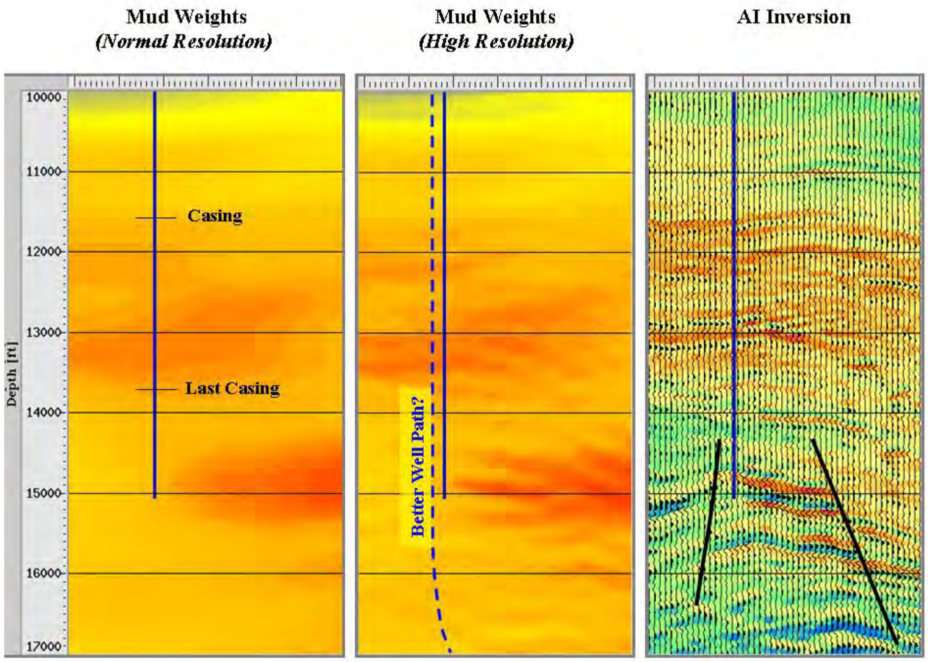

Figure 4. Comparison of the mud weights using normal resolution and high resolution seismic data and the acoustic impedance inversion. The wellpath and casing program could probably be better designed to avoid the abnormal pressure at the target around 17,000 feet.

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