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An Innovative Approach for Saturation Prediction for Prospect De-Risking.

At DLBARG, we have developed an innovative process flow based on frequency dependent analysis for measuring seismic dispersion in fluid saturated reservoir for saturation prediction. Primarily the process is applied on suitably processed stack data. The study can be extended to angle stack data, if available, to capture FAVO (Frequency dependent AVO). There are associated signal processing and analytical steps involved in the process flow. The application is to be fine tuned for the specific data conditions to best capture saturation anomaly.

Technical Details:

Among all petrophysical properties of a reservoir (like porosity, facies and saturation), hydrocarbon saturation is most difficult to be detected/estimated. Hydrocarbon might not have been encountered in the drilled wells or even if detected, zones are localized at the reservoir level. Propagating these discrete and thin zones away from the well or detecting sweet pods in the area based on seismic attributes remains a big challenge. Nevertheless, seismic remains to be the best tool for any property distribution in the area. Saturation estimation is vital for prospect de-risking and for improving POS (probability of success). Despite best idea of entrapment and reservoir quality, investment is a failure if the well turns out to be dry.

Innovative Low Frequency Analysis for DHI: This innovative approach is gaining lots of research attention in recent times. Several examples of field applications are reported.
It involves a paradigm shift in the understanding of seismic velocity in fluid saturated medium. Conventionally seismic velocity depends on the elastic properties of the medium, which in turn is affected by petrophysical properties like porosity, facies and saturation. There is no dependence on frequency i.e. all frequencies travel with the same velocity. Recent study has revealed, seismic velocity is also frequency dependent in fluid filled medium. **In a two phase system, when seismic waves travel from solid to liquid phase, dispersion occurs in liquid phase. Different frequencies travel with different velocity, increasingly lower frequencies travel with increasingly lower velocities. As a result, reflectivity also becomes frequency dependant. This effect is more pronounced in low frequency range up to 20-30 Hz. The dispersion is a measure of the permeability of the fluid. Hydrocarbon being much more permeable than water, in low frequency range they can be differentiated.** Reflectivity/Amplitude will stand up in the presence of Hydrocarbon. Being frequency dependent, this DHI works well in consolidated medium where conversional AVO fails. Facies related uncertainty is minimized because this works only in presence of fluid. Low frequency analysis is mostly applied on the properly processed/low

frequency preserved stack data. Recent studies have shown that this method can be extended to gather/partial stack data. AVO effect is reported to be more pronounced in low frequency range in fluid saturated medium. This process works better in clastic reservoir.

Core of this methodology is the spectral decomposition of seismic data to generate different time-frequency volume and measure some characteristics of the reflected wave from fluid filled medium. Signal processing techniques like CWT (Continuous Wavelet Transform) or SWFT (Short Window Fourier Transform) are used. Apart from frequency dependent amplitudes, spectral shape of reflected waves are measured/analyzed. Lowering of Dominant Frequency and faster decay of spectrum are additional measure of fluid presence. This study does not require any well control and hence is an un-supervised classification technique for frequency dependent prospect de-risking. Well information can be used for calibration and confidence building.

Examples:

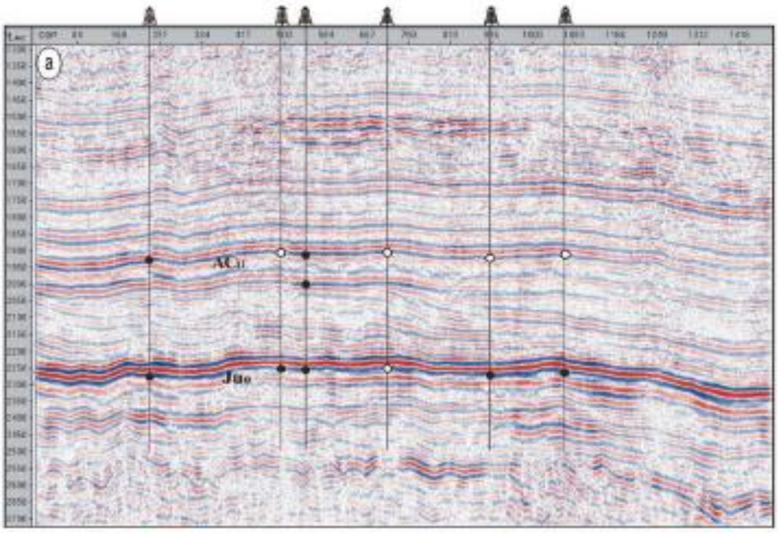

Figure-a: Black dots show oil saturated reservoir. White dots Show dry locations. Saturation cannot be guessed from the Conventional high frequency seismic data.

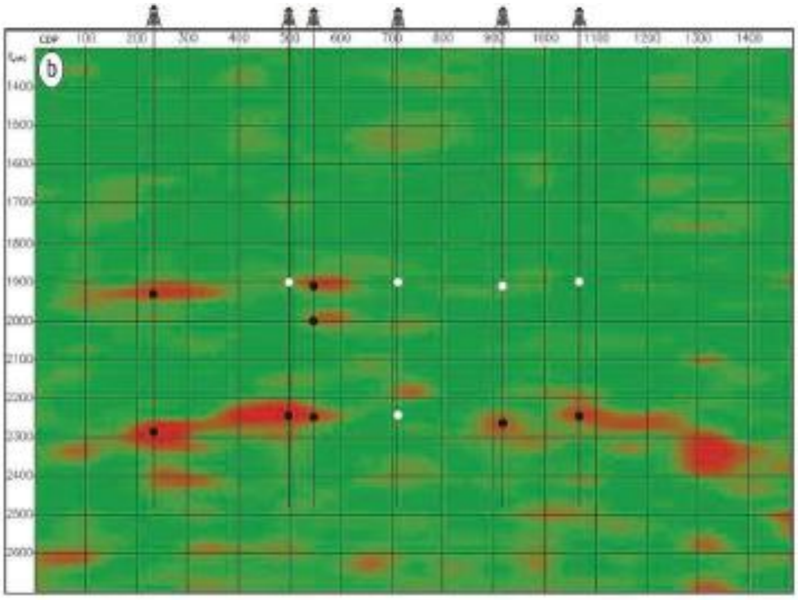

Figure-b: In the low frequency section < 15 Hz, oil zones
Are boosted and highlighted.

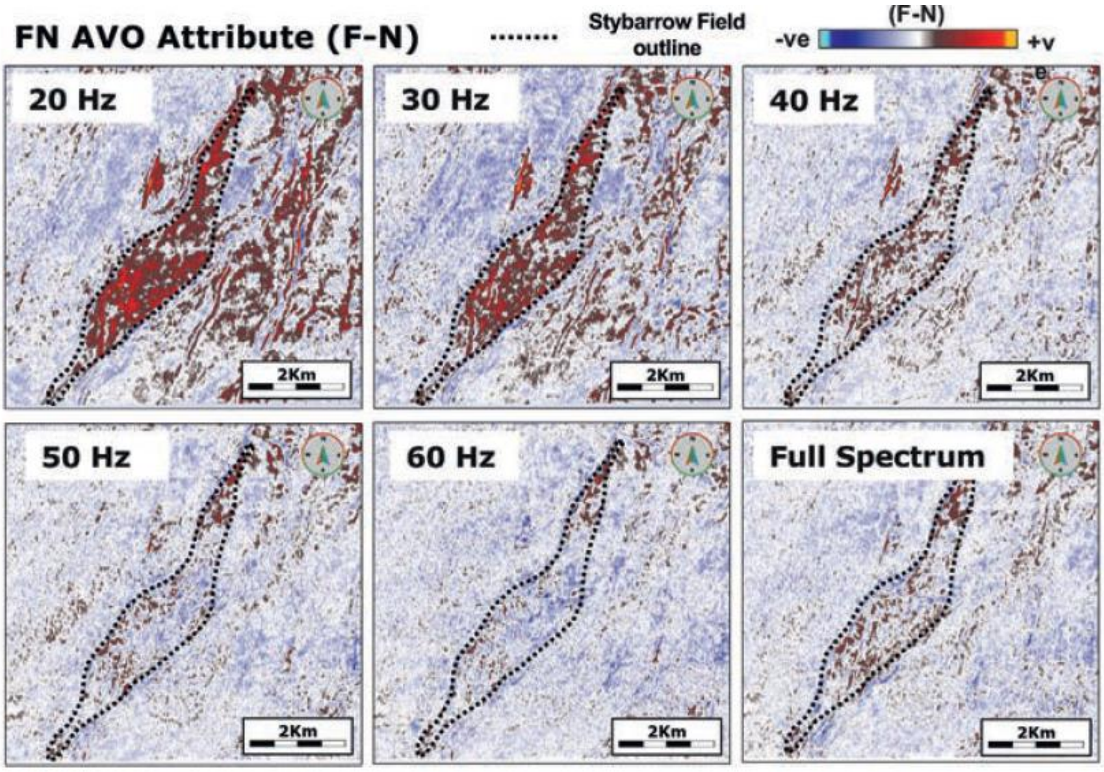

Figure- c: AVO (FAVO) attribute at the reservoir level at different frequencies. Low frequencies better highlighting the reservoir outline. Full spectrum result does not show any significant AVO anomaly.

Data Requirement:

Main requirement is the frequency preserved processed data. **Scrutiny of processing sequence of the existing data is essential.** Capability will be demonstrated on a selected line passing through a discovery well. If another dry well is also available on the same line it will be additional advantage to discriminate dry vs. wet. It is obvious that full potential will be achieved on a 3D volume. Bare minimum data is requested for this capability demonstration.

Data processing need be carefully implemented for this type of study. No processing should have distorted the original wave shape and frequency of the basic seismic wavelet. No spiking decon should be applied. If Predictive decon is applied, high Pd > 30ms may be acceptable. Amplitude Q compensation is not preferred. Only Q phase may be OK. In essence, a soft processing approach is to be adopted. In many of the modern day processing sequence, such steps (Decon, Ampl. Q etc) are avoided to preserve relative amplitude. A data set is to be selected which will be suitable for such a pilot study.

This unique technique is applicable for both clastic (both hard and soft) and carbonate reservoirs. However, for the pilot study we will request for a suitable seismic data from a clastic (preferably soft –i.e. low impedance clastic reservoir compared to overlying shale cap rock) regime with reasonable reservoir thickness (> 6-8 mts) , porosity (> 15 %) and saturation (>30-40%) . Well data is not particularly essential for analysis. However, for the pilot study we would like to have some basic well/reservoir information for understanding of the rock-physics modelling of the area and for calibration to fine tune/ judge the efficacy of the designed process. For hard clastics, conventional amplitude based AVO often fails. Frequency based DHI has a definite advantage over conventional AVO while dealing with tight clastics and carbonates.

Along with spectral decomposition, data analysis will involve spectral balancing, additional cleaning as required, frequency gather generation and attribute extraction, difference data generation, understanding of tuning effect etc. Discriminating parameters like dominant frequency, amplitudes and decay parameters will be analysed to arrive at final conclusion for saturation de-risking.

Following data is needed for the capability study:

1. PSTM Raw Stack data
2. Angle Stack (near and far) if available
3. Horizon information /zone of interest for focussed analysis
4. Reservoir information- Top/Bottom/Thickness of reservoir
   Well name, well status- dry/wet
   Location of well on seismic line
   Porosity, saturation, type of fluid
   Impedance of reservoir - high/low compared to cap shale

Deliverable:

A brief report of data analysis and results/recommendations.

References:

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