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Visualization, Analysis, and Interpretation of Seismic Attributes for Characterizing a Carbonate Reservoir

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Summary

The seismic data response carries information on rock properties. When properly transformed, analyzed and interpreted, seismic attributes can be used to qualitatively and quantitatively characterize a carbonate reservoir. Seismic amplitude, frequency dependent attributes and geometric attributes are visualized and interpreted to understand the carbonate layer heterogeneity. Seismic inversion is performed and Lamda-Mu-Rho (LMR) attributes are analyzed to identify the high porosity zones within the carbonate.

Introduction

Carbonates are a common petroleum reservoir rock. However compared with sandstone, the carbonate has demonstrated many challenges such as lateral inconsistency in rock properties, subtle facies changes, a shortened seismic expression due to its high velocity, and velocity dispersion due to permeability heterogeneity, etc. All of these characteristics make prospecting and quantitative analysis in carbonate reservoirs difficult.

Today's interpreters and reservoir characterization specialists have access to many types of seismic attributes including instantaneous attributes, frequency dependent attributes, geometry attributes, AVO, impedances and many other derivatives. These attributes carry rock and fluid information. Properly analyzed and interpreted, the attributes can be used to qualitatively and quantitatively characterize a carbonate reservoir.

Qualitative Approach

A Qualitative approach is used to identify the carbonate rock and its heterogeneity through visualizing and interpreting the seismic response of certain type of attributes. The following attribute response are examined and analyzed in this paper:

Amplitude
Instantaneous Phase
Frequency Dependent Attributes
    - Spectral Decomposition
    - Fluid Mobility
    - Spectral Decomposition Band Equalization
Geometric Attributes
    - Coherence and High Res Coherence
    - Lightscape

The carbonate platform can be identified and interpreted using amplitude. All of the attributes mentioned above are capable of imaging lateral variations within the carbonate layer. For example, figure 1 shows the 25 Hz spectral decomposition energy. The zone in red indicates strong reflections. Two of the wells that encounter the hydrocarbon are located in the low reflection zones in black.
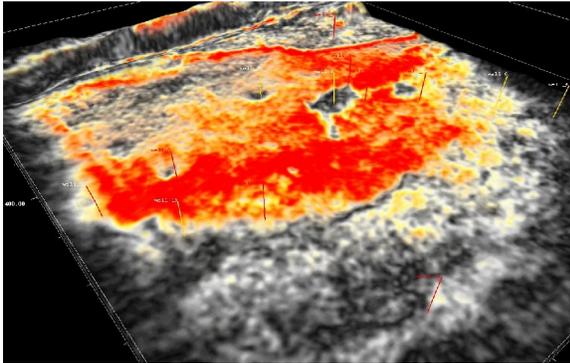
Figure 1 25 hz spectral decomposition energy. Red color indicates high reflection energy and the black, low energy.

Figure 2 captures high resolution coherence of the carbonate layer which identifies karst features and their lateral distribution and arrangement.
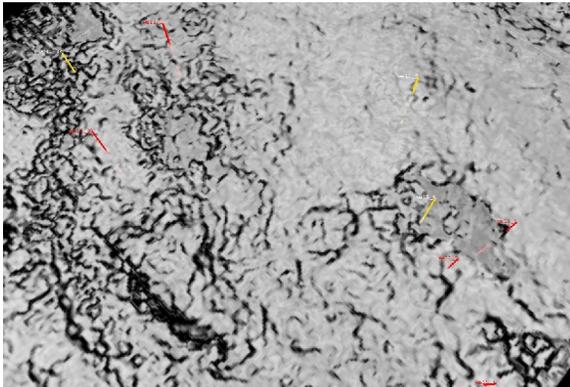

Figure 2 High resolution coherence

The key visualization techniques are formation sculpting and opacity editing, which assist the interpreter in revealing the internal configuration of the carbonate.

Quantitative Approach

A quantitative analysis of the data is needed to understand the rock properties of a reservoir. This analysis makes use of attributes such as P wave impedance, S wave impedance and their derivatives, which can be used to further their relationships to reservoir properties such as porosity, saturation and permeability. Generation of impedances is an inversion process. Accurate inversion of impedances requires integration of seismic data with the well data, quality seismic input, and sophisticated inversion algorithms.

Through core test and rock physical analysis, Lambda-Rho and Mu-Rho logs are identified to be sensitive to the carbonate facies (dolomites and limestone) and porosity. Figure 3 shows the crossplot of Lambda-Rho and Mu-Rho logs with porosity mapped as color. The polygons isolate the high porosity. The polygon on the left includes porosity from 10% to 16% and the one on the right from 6% to 10%
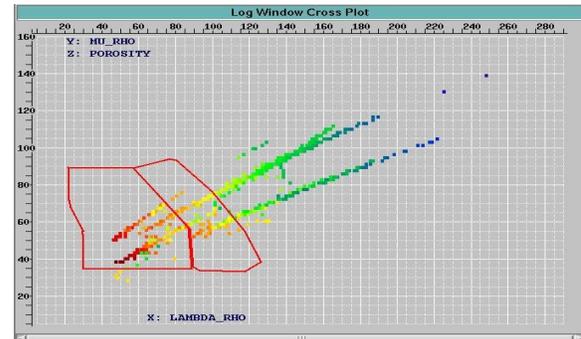

Figure 3 Crossplot of lambda-rho and mu-rho with porosity as color.

Lambda-Rho and Mu-Rho volumes can be generated from simultaneous inversion of P wave impedance and S wave impedance. Using the criteria defined in the log analysis, we can then isolate the high porosity zones in the carbonate. Figure 4 is the color volume generated by isolating the lambda-rho and mu-rho in zones defined by the polygons. The pink color is assigned to voxels that carry the data range from the polygon on the left while the blue color is assigned to voxels from the polygon on the right.
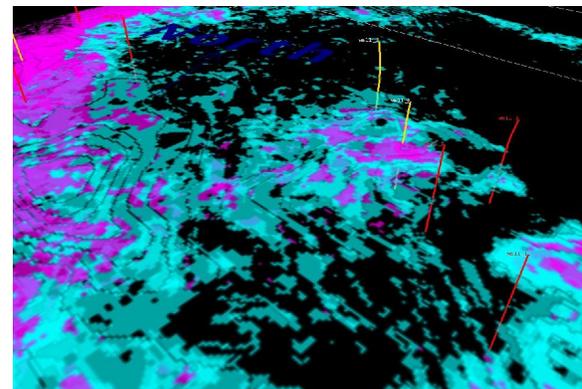

Figure 4 Color volume indicates high porosity distribution.

Co-visualizing the color volume with the high resolution coherence volume, we may see relationship between karstification and porosity, Figure 5.
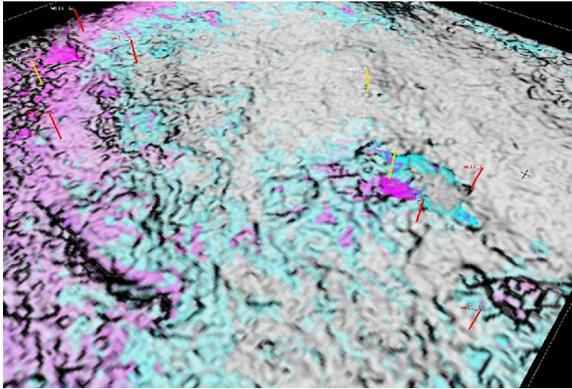
Figure 5 Co-Visualization of color volume from crossplot analysis and high resolution coherence.

Conclusions

As technologies in geophysics and computer science advance, we have powerful tools in carbonate reservoir identification and characterization.

Seismic attributes such as frequency dependent attributes and geometric attributes carry lateral variation information in a carbonate and can be used to qualitatively delineate the carbonate.

Seismic inversion and rock physics analysis make quantitative delineation of a carbonate possible. Great attention should be given to input data quality and calibration to wells in the inversion process. Simultaneous inversion should be applied to invert p and s impedances to ensure inversion accuracy, lateral consistency and resolution.

The power of visualization techniques can not be over-emphasized in the process of working on a carbonate reservoir.