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Modern Seismic Attributes Transforms Classical Structural & Stratigraphic Interpretation

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Summary

The advent and establishment of powerful 3D algorithms that extract hidden interpretive information over seismic volumes has changed remarkably the methodologies applied in seismic interpretation.

This paper briefly investigates the increasing role of seismic attribute analysis over 3D data volumes, describing their ancillary meaning to structural and stratigraphic seismic interpretation in prospect evaluation and geophysical development.

Introduction

Traditional seismic interpretation has gone through a remarkable transformation since the late 1980's and early to mid 1990's, largely due to the availability of 3D seismic and the advent of the interpretation workstation and visualization systems. The ability to interpret the seismic data on a workstation enabled the easy extraction of attribute information such as amplitude, phase and frequency, giving additional information and control to incorporate into the seismic interpretation, and ultimately the reservoir model. Structural and stratigraphic mapping continues to be the main initial work performed on seismic data sets, and with regards to regional 2D seismic data, it is the structural interpretation that brings the necessary understanding of basin regional fabric and diagenesis. Prospect evaluation and geophysical development of oil fields over 3D volumes are increasingly reliant upon newly developed algorithms that scan the data volumes for physical and geometrical seismic attributes.

Historically the progress in oil exploration started in the 1970's when direct detection of hydrocarbons – *bright spots* – became the hottest topic in seismic exploration. Bright spots are strong reflections that result from large changes in acoustic impedance and tuning effects, possibly due to fluid or gas charge such as when a gas charged sand underlies shale. They can also result from causes other than the presence of hydrocarbons, such as changes in lithology (Shuey, 1985). The critical component of the seismic processing step that enabled bright spot interpretation and analysis to be conducted with confidence was ensuring *relative amplitude preservation*. This simply means that the reflection strength of a signal on one part of the seismic data can be compared in a relative sense with the reflection strength of a signal in another part of the seismic data, for example, the comparison of near to far offset or angle in prestack data. Therefore, a large reflection that may occur as result of a gas filled sand reservoir could be seen as being larger than amplitudes for the brine filled nonreservoir part.

These observations regarding bright spots and their subsequent analysis, originally stimulated by Gulf of Mexico exploration, had a direct influence on subsequent seismic data processing methods and strategies in order to maintain relative amplitude information. Advances in acquisition, noise attenuation methods, model and moveout based multiple attenuation methods, adaptive subtraction methods and imaging advances in time and depth have all contributed to maintaining amplitude fidelity throughout the processing sequence and much improved quality of the final output data.

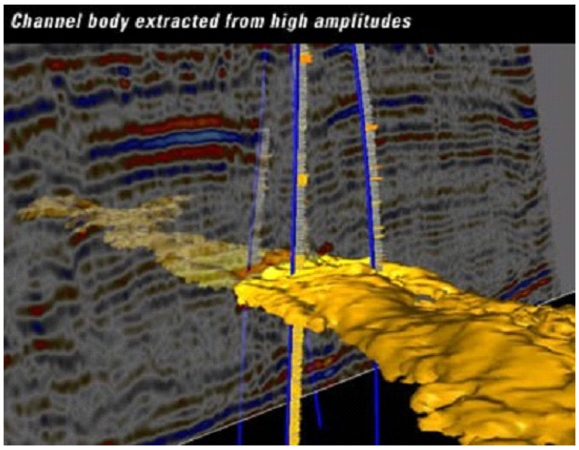

Figure 1: Channel feature followed through the tracking of bright amplitudes

Seismic Attributes – Amplitude, Frequency and Phase

Since the first classical paper on seismic attributes (Taner et al., 1977), the subject of attribute extraction and analysis has fascinated geophysical interpreters. That paper offered a simple mathematical transform by which the amplitude and phase of seismic signals could be separated, with direct implications over the stratigraphic interpretation of data. This ability to identify and measure certain waveform characteristics that could discriminate and characterize reservoir flow units facilitated the integration of seismic and petrophysical information.

With the advent of interpretation workstations and massive computer power, modern algorithms were developed specifically for attribute extraction. These represent interpretation tools that complement traditional structural and stratigraphic analyses of data.

Attributes have evolved into two broad categories, physical and geometric, for which there exists many new developments for specific seismic character determination and classification. These developments emulate progress that has also been made in imaging technology used in the medical sciences such as the analysis of coherence amid chaos, unsupervised mapping (Matos et al., 2006) and statistical data analysis. Herein we discuss some of the most practical attributes that are of timely value to the seismic interpreter.

Physical Attributes

The most utilized physical attributes bring pertinent additional information on reservoir stratigraphy, hence smartly influencing the analysis of prospects and the development of oil and gas fields (Vail et al., 1977). Among these are the following attributes ancillary to modern structural and stratigraphic interpretation.

- Amplitude Envelope
- Frequency and Phase
- Bright Spots - AVO Analysis
- Post Stack Inversion to Acoustic Impedance
- Spectral Decomposition
- Sweetness Attribute

A brief description follows over "Spectral Decomposition" and "Sweetness Attribute" that have been used frequently in Tertiary strata and deepwater.

Spectral decomposition is a methodology to reveal incised channels on large fans that may incise slope and basin toe in deepwater. This may compare favorably against the standard methods of amplitude, phase and frequency extraction and coherency attributes as it displays the channel image changes over desired windows of the frequency spectrum. Spectral Decomposition may also reveal valuable insight into the depositional history of a region.

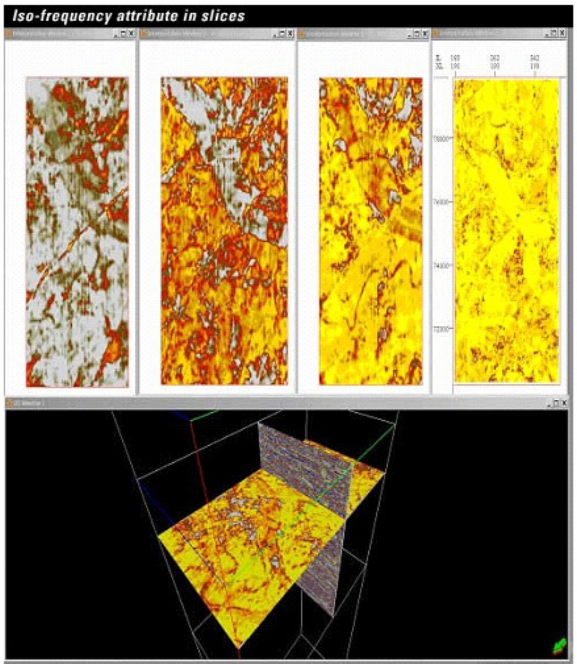

Figure 2: Iso-frequency attribute in slices displays the changing character of slice, low frequency corresponds to low velocity hence relating to possible hydrocarbon charge.

The spectral decomposition attribute transforms data recorded in space-time to spectral domains, for example using discrete Fourier transformation, and is useful in quantifying seismic waveform variations and thickness within reservoir zones of interests (Partyka and Gridley, 1997). It may often be the case that standard windowed attributes extracted are tuned to the response frequency of the dominant wavelet, which may result in subtle features being masked by this response. Once the spectral decomposition is performed, unsuspected features are revealed that may contribute further insight and understanding with regards to reservoir mapping, delineation of stratigraphic and structural features such as channel sands and complex fault systems.

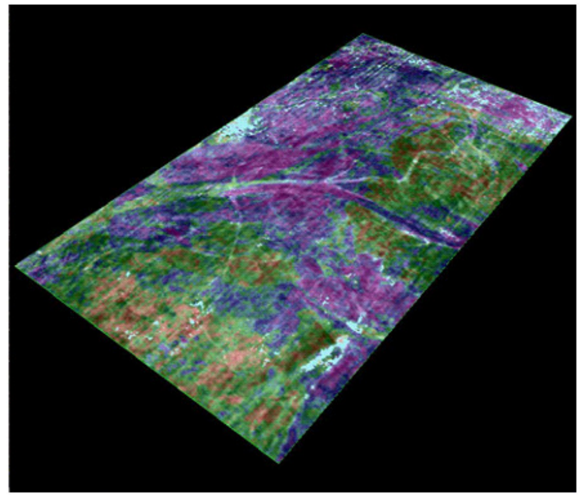

Figure 3: Spectral decomposition frequency slice in 3D inter-blended with instantaneous phase highlights a channel system in a Gulf of Mexico data set. The revealed lithologic features can be further investigated for charge estimation.

Sweetness attribute is obtained from reflection intensity and instantaneous frequency attributes, and is helpful in delineating subtle discontinuities such as pinch-outs and channels in stratigraphic traps. It can also be useful for distinguishing shales from sands and will be used in conjunction with spectral decomposition. It attempts to capture the ratio between amplitude and the square root of frequency. Sands tend to be associated with high amplitude and lower frequencies, hence co-blending Sweetness with Variance could give a good control of the extension of stratigraphic features, such as channels and pinch-outs.

Geometrical Attributes

Spatial discontinuities, such as faults and channels systems, may best be highlighted by attributes such as *coherence* or *variance* (Bahorich and Farmer, 1995; Marfurt et al., 1998; Pedersen et al., 2002. Methodologies and workflows now exist to enable the extraction of superior and higher fidelity discontinuity information from these attributes, or from the original seismic data.

During the exploration phase, the interpretation of the seismic data may focus on regional or major tectonic elements or fault systems, or alternately at appraisal and development stage, may focus on fault systems for understanding reservoir geometry and connectivity, which may ultimately affect hydrocarbon recovery. *Ant Tracking* is a proprietary tool for extracting fault information at any scale from seismic data, or may be extracted from a spatial discontinuity attribute volume, such as variance. The outputattribute dataset highlights fault surface features with greater clarity than may be directly interpreted from the original seismic data.

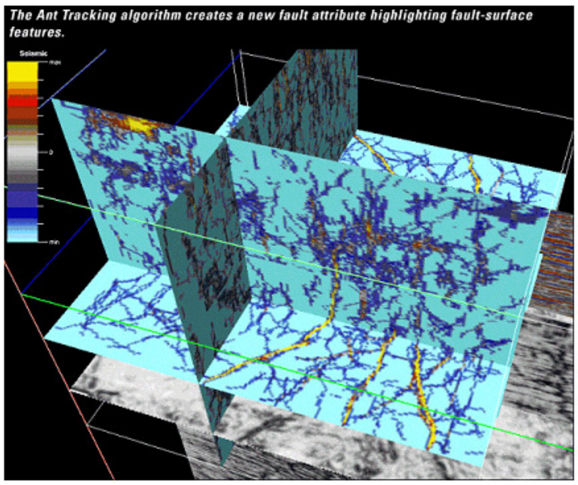

Figure 4: "Ant-Tracking" algorithm creates a new fault attribute dataset highlighting fault-surface features.

Conclusions

This paper has described some commonly utilized seismic attributes that are of complementary value to the information extracted through traditional methods of seismic interpretation. The subject of attribute extraction and analysis complements the traditional methods of structural and stratigraphic mapping interpretation. Seismic attribute extraction and analysis can bring new information and insight into stratigraphic and structural interpretations. Amongst the most useful modern maps are structural contours superposed on windowed spectral decomposition and "sweetness attributes" slices, combination maps that help reduce exploration and development risk.

Acknowledgments

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