Interpreting Fault-related Gas Leakage

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INTRODUCTION

Faults in extensional regimes can act as gas migration pathways when in contact with a hydrocarbon source. The gas presence associated with the leaking faults may be detected in seismic surveys.

Seismic response of waves traveling through low velocity intervals within gas-leakage zones shows incoherent reflections characterized by vertical chaotic patterns.

Interpretation of gas presence is supported by observations of amplitude anomalies and incoherent reflections within the leakage zone.

Seismic attributes such as semblance and curvature assist in detecting gas leakage.

Combination of multi-attributes can be used together to highlight the distribution of the leaking gas zones.

GAS LEAKAGE CHARACTERISTICS

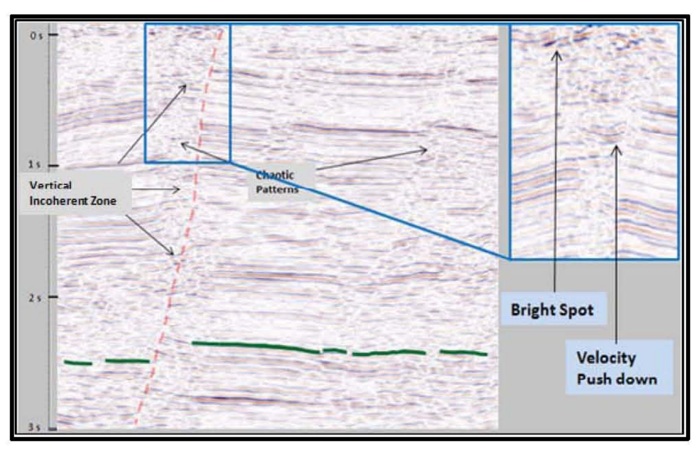
Gas Leakage shows acoustic changes appearing as vertical chaotic disturbances with amplitude anomalies associated with irregular distribution of low-velocity zones.

The vertical incoherence is a result of scattering, attenuation, and decrease in compressional velocity of waves passing through gas saturated pores.

The gas leakage often appears in vertical sections as cone-shaped distortion when associated with faults.

When gas replaces formation water, the contrast of impedance increases and causes the amplitude variations to show as dim and bright spots.

The decrease of P-wave velocity caused by changes in density and bulk modulus within the leakage zone explains the velocity push down in seismic sections.



Effects of gas leakage on seismic amplitude section. Non-sealing fault is indicated in red. In green, top Eocene sandstone reservoir which had hydrocarbon shows.

SEISMIC ATTRIBUTES

Attributes extracted from seismic data can predict the characteristic response of waves passing through gas.

Geometrical attributes were effective in increasing the contrast between the gas response and non-gas response in the data.

Geometrical attributes scan adjacent traces for each computed trace and describe the spatial and temporal relationships based on characters such as phase, frequency, amplitude, etc.

Examples of effective attributes used are semblance and curvature. semblance measures how similar the energy from a number of stacked traces compared to the total energy of all traces in that stack. Curvature is a measure of deviation at a certain point from a straight line.

Computations from the data can derive different curvature values such as maximum, minimum, mean, Gaussian, most positive and most negative curvatures. Most positive and most negative curvature always show the same polarity for geologic events such as faults, folds and fractures. Most positive and most negative curvature were found to be effective in detecting gas leakage in this study.

RESULTS

The presence of fault-related gas leakage can be observed on vertical seismic sections.

Leaking faults seemed to be charged by being in contact with hydrocarbon reservoirs or by encountering other leaking faults.

Seismic waves traveling through low velocity zones cause disruptions in coherency. This incoherency is shown as low semblance values along leakage zone.

Disrupted signals also result in high values of curvature. This is probably due to changes in geometric local dips as a result of scattering within the leakage zone. The dip changes are evident on dip variance attributes.

It was observed that the gas presence generally fell within the extreme ends of certain attributes' spectrum. For example, the leakage zone was represented by the lowest semblance and highest curvature values .

Attributes can be filtered to show mainly the representative leakage response.

Filtered attribute values could be shown on a horizontal slice to indicate the distribution of potential leakage in the survey.

Since computations of different attributes follow different algorithms, it is possible that non-leakage-related response showing in one attribute is avoided by another. When multi-attributes are filtered and overlain on each other, a better estimate of leakage distribution is shown. The more values from different attributes are shown at a given location, the higher the chance of having a leakage-like response at that location.

CONCLUSIONS

Gas leakages along normal faults can be identified in 3D surveys by observations of amplitude anomalies and incoherent reflections within the leakage zone.

The anomalies and signal incoherency are caused by scattering, attenuation, and reduction in P-wave velocity.

Attributes such as semblance and curvature are helpful in detecting unique responses caused by gas presence.

Multi-attributes can assist in delineating the gas-leakage distributions in the survey when filtered and combined together.

The approach described can serve to be useful in early stages of interpretation as well as a useful tool for monitoring gas injection and storage.

ACKNOWLEDGMENTS

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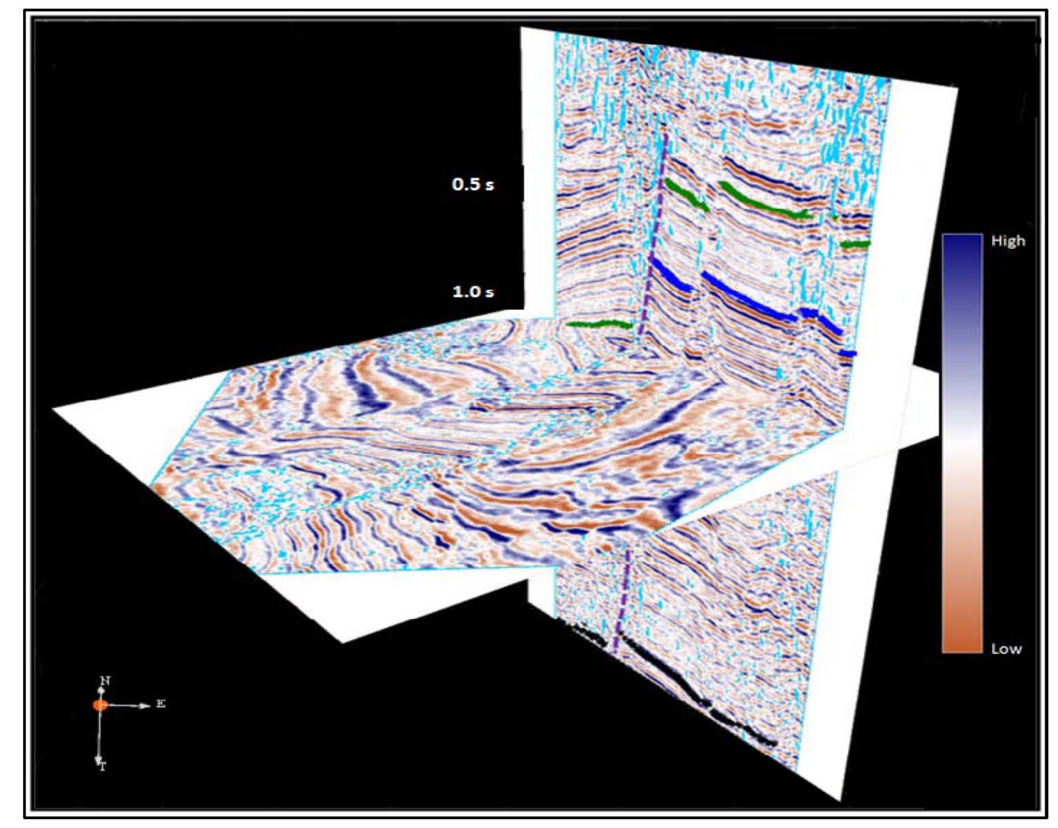
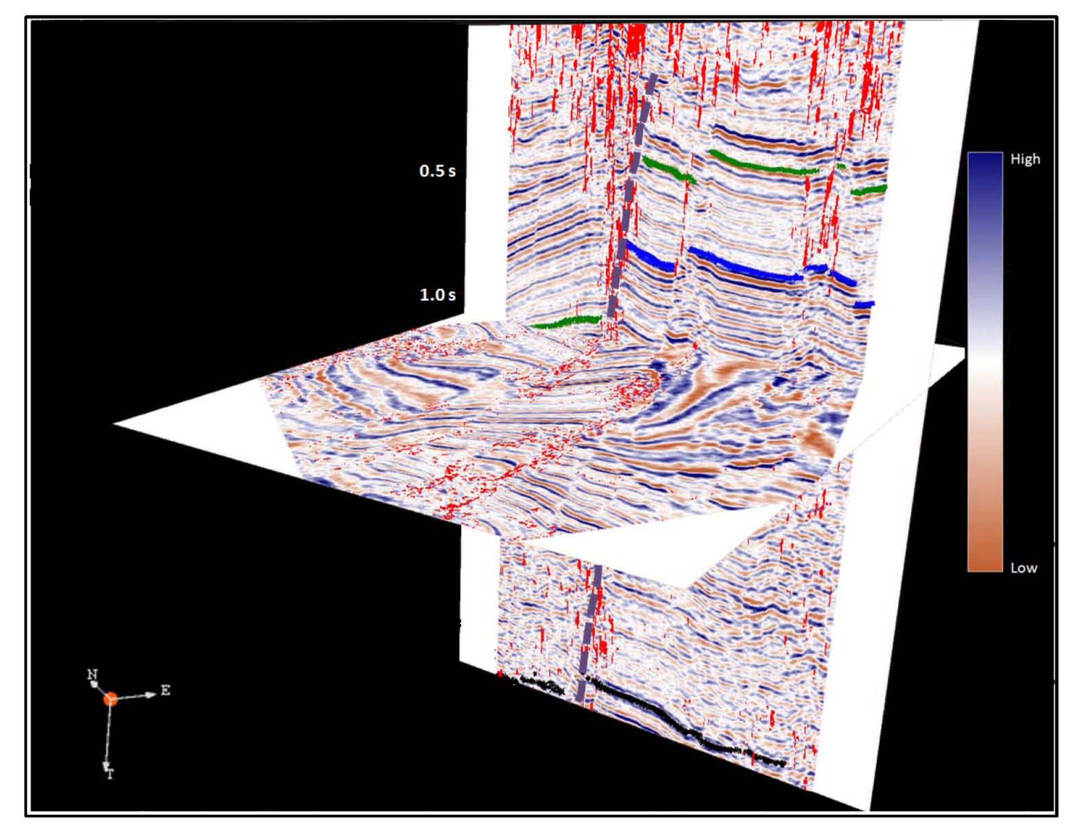
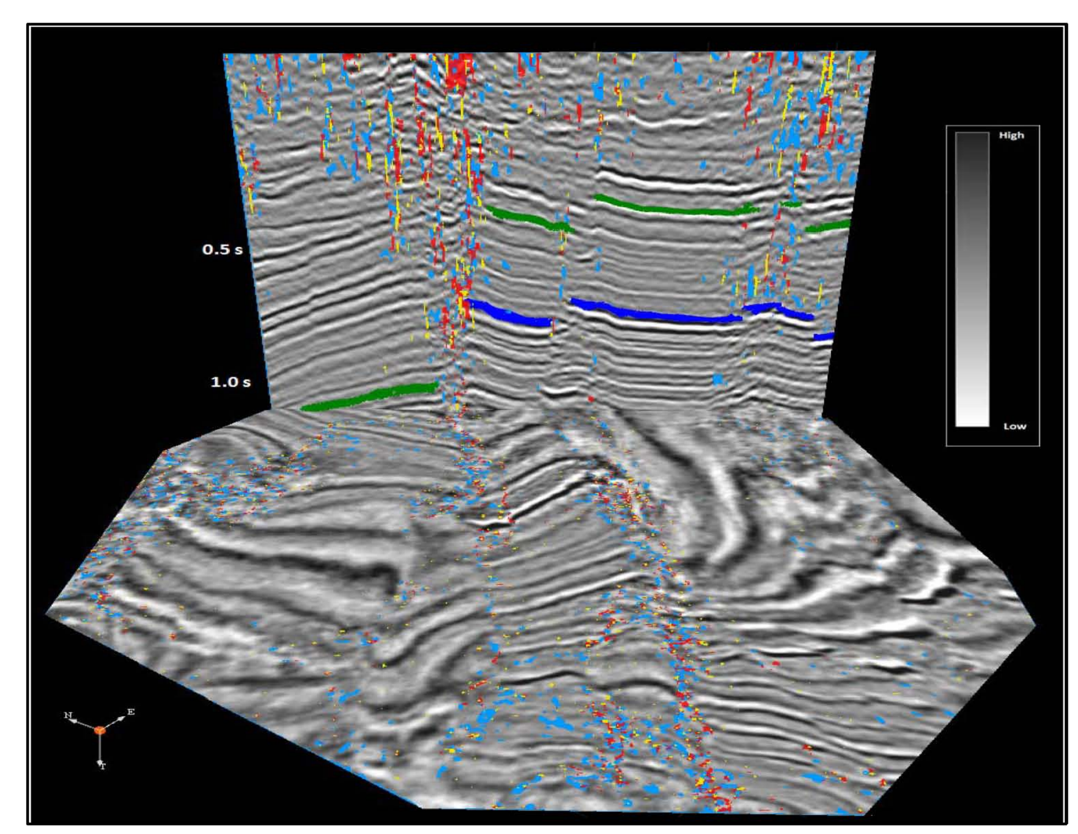


Distribution of low semblance (light blue) overlaid on amplitude sections. These values predict the location of leakage-like response. Higher semblance values were filtered (transparent). Leaking normal fault (purple) was interpreted to cut through the top of reservoir (black) and two other interpreted horizons (blue and green).



High values of most-positive curvature (red) overlaid on amplitude sections. These values predict the location of leakage-like response. Lower curvature values were filtered (transparent). Leaking normal fault (purple) was interpreted to cut through the top of reservoir (black) and two other interpreted horizons (blue and green).



Multi-attributes overlaid on vertical and horizontal amplitude sections to predict leakage locations. Filtered values are shown for semblance (light blue), most positive curvature (red) and most negative curvature (yellow). The more attributes shown within the same locality, the higher is the chance for gas presence.