Stress and fracture characterization in a shale reservoir, North Texas, using correlation between new seismic attributes and well data

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An Abstract of a Thesis

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ABSTRACT

In low primary permeability reservoirs, including tight sand or shale reservoirs, production of oil and gas is highly dependent on natural fractures and / or induced fractures created by high-pressure injection of fluid. The horizontal extent and azimuth of these induced fractures depend on present horizontal stress fields.

The goal of this study is to define the dominant horizontal stress field, as well as, if possible, the relative density and azimuth of vertical natural fractures using new seismic attributes, including azimuthal interval velocity, curvature and inter-azimuth similarity extracted from a 3D wide-azimuth seismic survey acquired in North Texas.

To reach this goal, I use E.U.R. (Estimated Ultimate Recovery) from 122 wells and micro-seismic monitoring of 6 hydrofrac'd wells to test the new seismic attributes with both quantitative (cross correlations) and qualitative (multi-layer attribute maps) techniques.

Only one seismic attribute, the fast interval velocity, has a significant (inverse) numerical cross-correlation with well production. But visual examination of multi-layer maps shows a correlation between creation of hydrofrac-induced fractures orthogonal to the regional main horizontal stress field and the azimuth of fast interval velocity when the velocity anisotropy is above a threshold of ~500 ft/s (150 m/s). I verified successfully this result numerically using E.U.R. of wells drilled after the 3D seismic acquisition.

In addition, the following observations may help those attempting a similar workflow:

- Stress fields are modified by hydrofracs; therefore, wells hydrofrac'd before the 3D seismic acquisition should not be used to calibrate seismic attributes such as azimuthal interval velocity;

- Inter-azimuth coherence images have disappointingly poor correlation with velocity anisotropy;

- In the south part of the survey, there is a visual correlation between the azimuth of the fast interval velocity and structural deformation imaged by volumetric curvature.