Fracture Detection and Imaging through Borehole Seismic Data

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Abstract

Objectives/Scope: Understanding of the subsurface complexity is critical for a successful exploration and development campaign. This is particularly challenging for unconventional carbonate fractured reservoirs. As the risk of total loss of circulation increases when drilling through highly fractured zones. In this analysis, we explore the effect of fractured formations on the loss of circulation fluids in drilling activities through Zero-offset Vertical Seismic Profile (ZVSP) data.

Methods, Procedures, Process: An offshore ZVSP has been acquired in a well, where multiple zones with potential fractures were drilled. Some were predicted prior to drilling and drilling parameters such as mud weight, and weight-on-bit were modified accordingly to prevent circulation loss. However, a total loss of circulation was unpredictable and detailed 3-component analysis of the ZVSP data demonstrated the presence of potential fractures. Additionally, we applied an elastic finite difference modelling through different fracture distributions at loss of circulation level to regenerate the seismic gathers. The forward elastic modeling reveals that different fracture distributions produce different seismic responses.

Results, Observations, Conclusions: Under Linear Slip Theory assumption the fractures are introduced as weakness planes. We modify the stiffness matrix to resemble an induced anisotropy that appears when a medium is subjected to regional stresses. Thus causing fractures while attaining a new system of equilibrium stresses in the subsurface. The elastic properties of the stiffness matrix are highly influenced by the background rock properties, fractures' normal and tangential compliances, and fractures' spatial density. In our application, all the fracture carry similar elastic properties, however, the number of fractures per unit distance exhibit variable spatial distribution. Our results reveal that field diffraction patterns in the radial and transverse components can be potentially induced by a fracture mechanism with a relative estimate of the fracture infill, extent and orientation. In the presence of random fracture distribution, diffraction from random clusters interfere and act as secondary sources which are clearly observed in the transverse component. Using the fracture properties in our examples, the diffractions are mostly P-S converted waves. These diffractions appear as hyperbolas on synthetic VSP data even for the case when the seismic wavelength is much smaller than the average fracture-spacing.

Novel/Additive Information: The least-square diffraction migration of both the synthetic and field datasets succeeded in localizing the fracture planes in their subsurface location with a sensitivity to fracture density in the modeled distributions. We further realized that even a ZVSP analysis complemented by an elastic seismic modelling of fractured media may lead to vital information about the nature of total loss of circulation in fractured formations.