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LandTech Enterprises has provided services to major oil companies

SHEAR WAVE SPLITTING

Detecting fracture patterns and permeability anisotropy

Knowledge of a subsurface fracture system is of vital importance for an accurate evaluation of the potential and day-to-day production of a reservoir. LandTech has developed a methodology to assess 3D fracture patterns, their density (number of craks per unit volume) and outline zones of high permeability in areas where has installed passive seismic networks and at a small extra cost. The method is based on the shear wave splitting phenomenon by analyzing the recorded waveforms.

The splitting phenomenon occurs when a shear wave propagates through an anisotropic medium (e.g., an inherently isotropic body of rock which is fractured) and splits into a fast and a slow shear-wave (Fig.1). The polarization of the fast S-wave (φ) is shown to correlate with the strike and the dip of the main crack system traversed by the wave. The delay time (Δt) between the arrivals of the fast and the slow shear-waves is proportional to the crack density (or the number of cracks per unit volume).

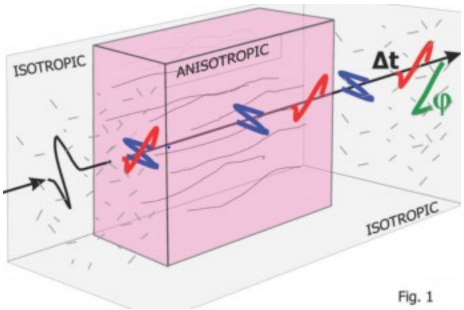

Fig. 1

These two properties are exceptionally appealing since they provide direct means of describing fracture characteristics in a methodical way and thus they help delineate major subsurface fluid flow directions through stress-aligned cracks (Fig.2). The information gathered on crack density also offers good prospects of recognizing areas of increased permeability within the reservoir rock (Fig.3).

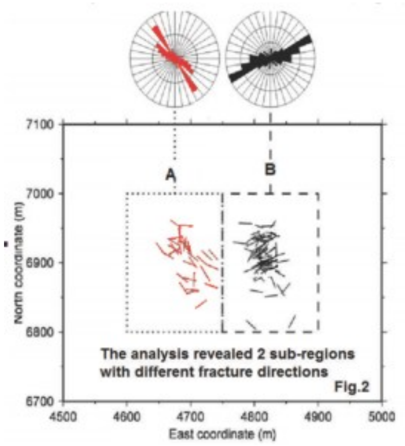

Fig.2

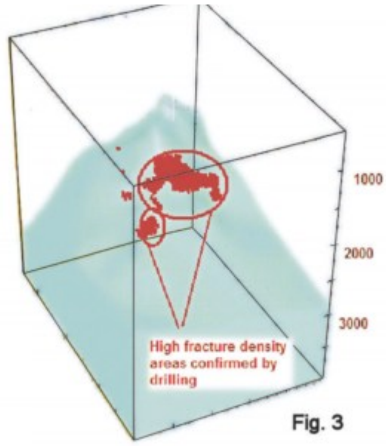

Fig. 3

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LandTech has developed a method for mapping subsurface fracture densities using the time differences of split shear waves from microearthquakes. These measurements are then inverted using backprojection tomography to locate the spatial distribution of crack density.

To model the effects of crack-induced anisotropy on shear-wave behaviour, the fractured medium is represented by an elastic continuum with anisotropic properties that reflect the configuration of the cracks. The elastic stiffness matrix for transversely isotropic media is used to simulate the general 3D mechanical properties of the fractured solid. By evaluating the eigenvectors and eigenvalues of related Christoffel matrices, synthetic fast shear-wave polarizations and time delays can be calculated for prescribed crack models. The fracture inversion scheme employs both parameters φ and δT. Station-by-station inversion for subsurface crack strike, dip, and density is performed through successive comparisons of observed and synthetic fast shear-wave polarizations and time delays. The best fitting fracture model relies on simultaneous minimization of both φ and δT residual functions in the model-space of crack strike and dip for different crack densities. This minimization is accomplished by a nonlinear least-squares algorithm.