V010 AZIMUTHAL AVO ANALYSIS OF A VERTICALLY FRACTURED RESERVOIR

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INTRODUCTION

Good knowledge of fracture systems is of great importance in reservoir characterization. This requires mapping of fracture properties away from well locations, which, to significant distances, can only be done with seismic data. The presence of closely spaced vertical fractures in an isotropic background leads to a transversely isotropic medium with a horizontal symmetry axis (HTI), with some restrictions on the parameters. The anisotropy of an HTI model has a first-order influence on the amplitude versus offset and azimuth (AVO-A) response at an interface between two elastic media (Rüger and Tsvankin, 1995). Using 3-D P-wave reflection data, AVO-A analysis is particularly well suited for fracture characterization, because it provides local information about the anisotropy at the target horizon.

We have developed a new approximative expression for the scattering matrix at an interface separating two anisotropic media of arbitrary symmetry. This is done by treating the two media in contact as perturbations from an arbitrary chosen reference medium (Banik, 1987, Thomsen, 1993), in contrast to the average medium often used (Aki and Richards, 1980, Ursin and Haugen, 1996).

Using this model we will analyze the impact of fracturing in a model consisting of a shale over a vertically fractured sandstone, as shown in Figure 1. The shale is represented by a transversely isotropic medium with a vertical symmetry axis (VTI), and is parameterized in terms of the Thomsen (1993) parameters. The effect of the vertical fracturing on the elastic properties of the sandstone is calculated using effective medium theory (Nichols, Muir and Schoenberg, 1989, Haugen and Ursin, 1996). The vertically fractured sandstone can then be represented by an HTI medium, parameterized in terms of an isotropic background medium and two fracture parameters δ_n and δ_t .

NUMERICAL EXAMPLE

The approximate expression for the P-wave reflection coefficient was derived in the crack-normal plane (normal to the aligned cracks) and in the crack-strike plane (parallel to the cracks). Numerical results were computed for a VTI medium with parameters $\alpha_1 = 2.26$, $\beta_1 = 1.43$, $\rho_1 = 2.2$, $\epsilon_1 = 0.07$, $\delta_1 = -0.05$, $\gamma_1 = 0.15$ over an HTI medium with parameters $\alpha_2 = 2.5$, $\beta_2 = 1.5$, $\rho_2 = 2.2$, $\delta_{n2} = 0.2$, $\delta_{t2} = 0.1$. The exact P-wave reflection coefficient is shown in Figure 2 as a surface plot with the approximations superimposed in the crack-normal and crack-strike plane as single curves. The reflection coefficients in the two symmetry planes are plotted to the right in Figure 2, together with the reflection coefficient for the VTI medium overlying the isotropic background medium. The reflection coefficient is increasing with offset in the crack-strike plane, while it is decreasing with offset in the crack-normal plane due to the influence of the cracks. Similar amplitude behavior has been observed in real seismic data by Lynn, Simon, Layman, Schneider, Bates and Jones (1995).

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Shale	
$\alpha_{01} , \beta_{01} , \rho_1$	Thomsen parameters
$\epsilon_1 , \delta_1 , \gamma_1$	
Vertically fractured sandstone	
$\alpha_2 , \beta_2 , \rho_2$	Isotropic background
$\delta_{n2} , \delta_{t2}$	Fracture parameters

Figure 1: Model and parameterization

Figure 2: AVO-A response for the P-wave reflection. The exact reflection coefficients with the approximations superimposed (left). The response in the crack-strike and crack-normal planes (right).

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