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Evaluation of anisotropy and stress in the Clearwater Formation, using seismic and well log data

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Abstract

A method of characterizing the stress field by integrating anisotropy information from well logs and seismic data was used to predict local variations in the horizontal stresses within the Clearwater Formation.

Fractures within the caprock overlying a reservoir are very important as they control the mechanical behavior of the rock. Anisotropy of a fractured rock carry unique information about the orientation and density of fracture distribution, as well as orientation and magnitude of the principal stresses. For a material with horizontal transverse isotropy, the elastic moduli cannot be recovered only from density and compressional and fast and slow shear wave data recorded in a borehole. However, the logs may be interpreted directly in terms of compressional velocity of the intact rock. Consequently, this opens the possibility to infer both the normal and tangential fracture weakness parameters. The minimum and maximum horizontal stress can then be expressed as a combination of the normal fracture weakness, Lame's coefficients (Lambda and Mu), and vertical stress, and can be further used to evaluate the differential horizontal stress ratio.

This method was used to estimate the fracture weaknesses and magnitude of horizontal stresses within the Clearwater Formation based on dipole sonic wells. Mini-frac records from wells showed a good consistency between the two estimations, with less than 5% differences. However, in one well the mini-frac tests estimated a very large value of the minimum horizontal stress. Away from wells, the differential horizontal stress was predicted using Lame's coefficients seismic volumes determined by PP-PS prestack inversion.

Results from this method were compared with outputs from amplitude variation with azimuth inversion. A considerable consistency was observed between the anisotropic gardient and the differential horizontal stress ratio. These two methods indicate, independently, that the largest magnitude of anisotropy occurs in areas of high ratio of stresses, while smaller magnitudes are being tied to smaller ratios.

Although the method was used on an oil sands environment, it can be applied to both unconventional and conventional reservoirs.