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Lithological Controls on Mechanical Anisotropy in Shales to Predict In Situ Stress Magnitudes and Potential for Shearing of Laminations During Fracturing

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Accurate and repeatable assessments of in situ stress magnitudes and orientation in unconventional reservoirs can be complicated by the heterogeneous, inelastic, and/or anisotropic mechanical properties of these rocks. The associated vertical and lateral variation in pore pressure and stress through the target zones and bounding intervals can further complicate this effort. For these reasons, some additional factors need to be considered beyond the typical workflow of determining stress state from mini-frac type data and using this data to calibrate log derived stress profiles. We present some case study examples from hydrocarbon-producing shales where a more rigorous analysis of the injection test data and of the shale mechanical properties has allowed a more accurate and repeatable assessment of in situ stress and potential for lamination shearing. Horizontal fracture growth through shear activation of bedding-parallel fabric can be a preferred fracture propagation mechanism in these shales and this behavior can be diagnosed by this improved workflow. In one case study example, in the tight gas Montney siltstone of Western Canada, shear strength anisotropy is shown to be very significant, with bedding parallel shear cohesion less than 10% of the bulk rock cohesion. It is shown through theory and through pressure transient analysis of case study minifrac injection data that shearing of laminations can be predicted, diagnosed and minimised during hydraulic fracturing stimulation. This shear fracturing mechanism is also stress dependent and its understanding requires assessment of all in situ stress magnitudes, not just minimum horizontal stress. An improved method of determining these stress magnitudes is described through multi-component acoustic measurements in core samples. In this way, a petrophysical relationship can be established between anisotropy parameters and rock properties.