P-WAVE AND S-WAVE ANGLE DEPENDENT VELOCITY PREDICTION THROUGH PRESSURE-DEPENDENT COMPLIANCE COMPONENTS

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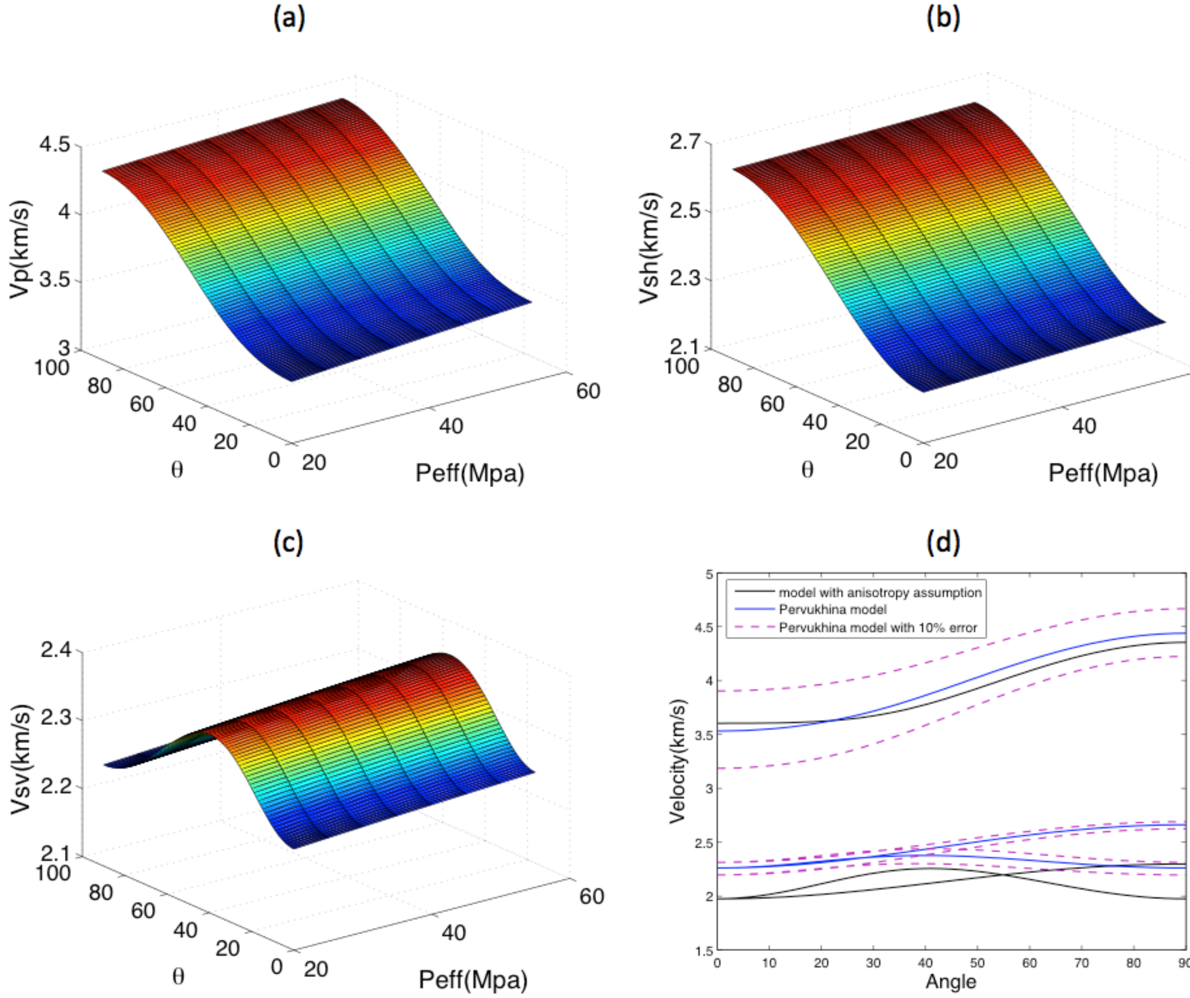
ABSTRACT

Worldwide interest in shale as a hydrocarbon resource requires new approaches to reservoir characterization. Due to its intrinsic anisotropic properties (commonly VTI), the existing isotropic rock physics models are no longer suitable in shale studies. Therefore, it is important to utilize anisotropic rock physics models for shale in further research. These anisotropic models should account for the phase velocity with non-zero propagation angles with respect to the reference frame. My work was aimed at developing a feasible method to predict angle-dependent velocities (P, SH and SV) in a VTI system. In such an anisotropic system, wave velocities are determined by the elastic tensor with five independent components. The well data I used was from the Haynesville Shale, core samples from this well, and an analogous hard shale sample. The model used to describe the VTI system treats the compliance tensor components as an exponential function of effective pressure. I built an integrated workflow to model the compliance tensor from stress-dependent vertical P-wave velocity lab measurements and then predicted the velocities. Then I used the log data and analogous shale data to estimate the uncertainty. The difference between well log and modeled P-wave results at a test location was 3%. The modeled P-wave results fell between 10% uncertainty estimates over the range of propagation angles. For the S-wave, the difference was much larger due to the lack of measurements, but they showed the same angle-dependent variation trends. Therefore, the analogous data was required to provide reliable S-wave velocity. Applying these results to field seismic data, we could reliably predict the angle-dependent P-wave velocity at the seismic scale.



Predicted velocity against propagation angle and effective pressure, colored in velocity. a) P-wave; b) SH-wave; c) SV-wave. As the increasing of propagation angle, Vp, Vsh increase, and Vsv shows more complex behavior. d) shows the uncertainty of the predicted velocities (blue lines). Black lines are the log-based angle-dependent velocity using hard shale Thomsen parameters and green dash lines are predicted velocity with 10% error. P-wave uncertainty is less than 10%, while S-wave uncertainties are larger.