Feasibility of Prediction of Principal stress from reflection seismic data

Orientations and magnitudes of subsurface principal stresses are crucial information for understanding the structure and tectonic processes inside the Earth. The stress state in the Earth's crust controls stress concentration around wellbores and, therefore, plays a critical role in wellbore instability and fluid flow in fractured reservoirs. Most of the subsurface stress studies are based on the analyses of well log data and core plug measurements, which only provide accurate information at some specific locations. On the other hand, seismic inversion can provide an even greater comprehensive description of the subsurface geology but at a lower vertical resolution.

Therefore, my work entails the following three closely related steps: (a) Relate stress to anisotropy. In my current work, I derive stress to stiffness relationship from laboratory measurements from a mudrock sample. This analysis demonstrates that the stiffnesses are anisotropic under axial stress. (2) Mesh-free anisotropy media forward modeling. I employ the radial basis-function generated finite-difference (RBF-FB) method for the mesh-free discretization scheme to generate synthetic seismograms based on a realistic model derived from laboratory data and demonstrate the effect of stress on seismic data. (3) Seismic inversion sensitivity analysis. I utilize a global optimization method called Very Fast Simulated Annealing (VFSA) to demonstrate the feasibility of seismic inversion for principal stress. The forward modeling procedure in the VFSA method is carried out via the mesh-free RBF-FD method. My results show that the magnitudes and angles of the stress have noticeable effects on the seismic response that can be estimated by seismic inversion.

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