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Estimating depths to subsurface discontinuities using receiver function velocity analysis

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Velocity analysis, an important component of reflection seismic processing, estimates subsurface seismic velocities by transforming a common receiver gather's hyperbolic move-out curve to an equivalent zero-offset gather. We adapt and apply velocity analysis to earthquake seismology by utilizing P-to-S and S-to-P type receiver functions. These receiver functions consist of converted phases (such as Ps, PpPs and PsPs+PpSs) and their arrival times vary with ray parameter. Advances or delays of converted phases due to 3D heterogeneity and/or undulating discontinuities (where the conversion occurs) may degrade a direct stack of converted phases made using a reference Earth model. However, the phases' time shifts can be used as constraints on estimates of velocity perturbations; the correct velocity perturbations will produce the most coherent stack. Our technique jointly optimizes the average correlation values of converted phases in a seismic station's receiver function gather with a process driven by Very Fast Simulated Annealing (VFSA). The best estimates of 1D shear wave velocity and Poisson's ratio profiles obtained from optimization can be used to migrate P-to-S and S-to-P receiver functions to the depth domain. Poisson's ratio and shear wave velocity profiles obtained for a 2D seismic broadband deployment are interpolated to form 3D shear and compressional wave velocity models for use in Common Conversion Point (CCP) stacking.

We applied the velocity analysis technique to broadband seismic data recorded in southeastern New Mexico and west Texas. Our results reveal an abrupt increase in lithospheric thickness from the Rio Grande Rift to the Great Plains craton. Ps results show that the Moho ranges from 36-60 km in the region, while Sp results show variations in the seismically-determined Lithosphere-Asthenosphere Boundary of 75-112 km. Areas of thickened crust and lithosphere overlie an anomaly identified previously via tomography and are elongated in a northwest-southeast direction. We speculate that the thickened crust and lithosphere may be due to removal of the lower lithosphere by a process that is associated with east-west extension, and thus the northward propagation of the Rio Grande Rift.