Shear velocity structure beneath the central United States: implications for the origin of the Illinois Basin and intraplate seismicity

We investigated the lithospheric structure beneath the North American Midcontinent, including the Illinois Basin and three intraplate seismic zones. By measuring Rayleigh wave phase velocities from teleseismic earthquakes recorded at USArray Transportable Array and OIINK (Ozarks-Illinois-INdiana-Kentucky) Flexible Array stations, we obtained new estimates of lithospheric shear velocities for the Illinois Basin (IB), the New Madrid Seismic Zone (NMSZ), the Wabash Valley Seismic Zone (WVSZ) and the Ste. Genevieve Fault Zone (SGFZ). A failed rift arm, the Reelfoot Rift (RR), sits beneath the NMSZ and extends into the southern Illinois Basin. We find that the southern IB possesses high mid-crustal velocities (>4.2 km s^{-1}) at depths between 25 km and 35 km (map left). The observed high velocities at mid-crustal depths beneath the southern basin may correspond to high-velocity mafic intrusions that were emplaced into the crust during rifting. The high-density mafic intrusions may have contributed to the subsidence of the southern IB. We also observe relatively low velocities (< 4.65 km s^{-1}) in the mantle beneath the NMSZ at depths between 90 and 125 km (map right), compared with the average shear velocity of 4.7 km s^{-1} outside of the rift. The low upper mantle velocities also extend beneath the WVSZ and the SGFZ. Based on exploring the sensitivity of seismic velocities to a range of thermal and compositional variations, we infer that the low mantle velocities would likely not result from elevated temperatures alone but require a contribution from increased iron content and the presence of water. The compositional heterogeneity of the upper mantle would lead to a weak zone. The crustal seismic zones may then correspond to locations where deformation has been localized within the mantle due to their lower integrated lithospheric strength. The tectonic history of the region including rifting and interaction with a mantle plume can introduce these heterogeneities and cause velocity reduction. Similar orientations for the NE-SW low-velocity zone, and the Reelfoot Rift suggests a rifting related origin for at least the southern portion of the area of reduced velocities.