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Dynamics of the Afro-Arabian Rift: new insights from shear-wave splitting

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The Arabian plate is located east of the active Red Sea spreading center and north of the Afar hot spot. Seismic data provide an effective means of examining the structure of the lithosphere and asthenosphere beneath the Arabian plate. The Saudi Geological Survey (SGS) operates a nationwide digital seismic network with broadband seismometers. The data from this network allows us to measure the seismic anisotropy of the crust and upper mantle beneath the Arabian plate. We measured shear wave splitting at 146 stations in the SGS network using the seismic phase SKS that passes through the core as a P-wave and is converted to a S-wave at the core-mantle boundary almost vertically beneath the seismographic station. Most of the splitting observations across Saudi Arabia show N-S alignment of the fast shear-wave direction, consistent with previous studies based on more sparse data. The delay times between the fast and slow shear waves (i.e., the magnitude of the splitting) decrease from western Saudi Arabia to the Arabian Gulf, whereas the lithosphere thickens. This anti-correlation between splitting delay time and lithospheric thickness indicates that the source of the seismic anisotropy is not within the lithosphere, but is within the convecting asthenosphere. The measured N-S orientation of the fast direction is inconsistent with either: (1) convective flow perpendicular to the axis of the Red Sea spreading center, or (2) the N40°E absolute plate motion of the central Arabian plate. The N-S orientation of the fast direction is consistent with both: (1) the long-term (past 50 Ma) convergence direction of the African plate with Europe, and (2) northward asthenospheric flow originating at the Afar hot spot. The fast direction of shear-wave propagation rotates counter-clockwise beneath the eastern portion of the Arabian plate. We infer that this rotation is due to asthenospheric flow that is blocked by the steeply-dipping Zagros subduction zone. The asthenospheric flow continues northward toward Turkey where there is an opening in the plate, that is, a slab gap.