S-wave velocity structure of the Arabian Shield upper mantle from Rayleigh wave tomography

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Abstract

The shear wave velocity structure of the shallow upper mantle beneath the Arabian Shield was modeled by inverting Rayleigh wave phase velocity measurements between 45 and 140 s together with previously published Rayleigh wave group velocity measurement between 10 and 45 s. For measuring phase velocities, we applied a modified array method to data from several regional networks that minimizes the distortion of raypaths caused by lateral heterogeneity. The new shear wave velocity model shows a broad low velocity region to depths of ~150 km in the mantle across the Shield, and a narrower low velocity region at depths ≥ 150 km localized along the Red Sea coast and Makkah-Madinah-Nafud (MMN) volcanic line. The velocity reduction in the upper mantle corresponds to a temperature anomaly of ~250 – 330 K. These findings, in particular the region of continuous low velocities along the Red Sea and MMN volcanic line, do not support interpretations for the origin of the Cenozoic plateau uplift and volcanism on the Shield invoking two separate plumes. When combined with images of the 410 and 660 km discontinuities, body wave tomographic models, a S-wave polarization analysis, and SKS splitting results for the Arabian Peninsula, the anomalous upper mantle structure in our new velocity model can be attributed to an upwelling of warm mantle rock originating in the lower mantle under Africa that crosses through the mantle transition zone beneath Ethiopia and moves to the north and northwest under the eastern margin of the Red Sea and the Arabian Shield. In this interpretation, the difference in mean elevation between the Arabian Platform and Shield can be attributed to isostatic uplift caused by heating of the lithospheric mantle under the Shield, with the significantly higher elevations along the Red Sea coast possibly resulting also from lithospheric thinning and dynamic uplift.