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The lithospheric shear-wave velocity structure of Saudi Arabia: Young volcanism in an old shield

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We are utilizing receiver function and surface wave dispersion data to investigate the lithospheric shear-wave velocity structure of Saudi Arabia. The Arabian plate consists of the western Arabian shield and the eastern Arabian platform. The Arabian shield is a complicated mélange of several Proterozoic terrains, separated by ophiolite-bearing suture zones and dotted by outcropping Cenozoic volcanic rocks (so-called harrats). The Arabian platform is covered by thick Paleozoic, Mesozoic and Cenozoic sedimentary rocks. To understand the geo-dynamics and present-day geology in western Saudi Arabia, the origin and activity of the harrats needs to be investigated: are they controlled primarily by a local mantle plume underneath western Saudi Arabia or by lateral mantle flow from the Afar and (perhaps) Jordan hotspots?

In our study, we first estimate Vp/Vs ratios by applying the H-κ stacking technique and construct local shear-wave velocity-depth profiles by jointly inverting teleseismic P-receiver functions and Rayleigh wave group velocities at 56 broadband stations deployed by the Saudi Geological Survey (SGS). Our results reveal significant lateral variations in crustal thickness, S-velocity, and bulk Vp/Vs ratio. The Arabian shield has, on average a $\sim$34 km thick crust with Vs $\sim$3.72 km/s and Vp/Vs $\sim$1.73. Thinner crust ($\sim$25 - 32 km thick) with strong lateral variations is present along the Red Sea coast. In contrast, the Arabian platform reveals a $\sim$41 km thick crust with Vs $\sim$3.52 km/s and Vp/Vs $\sim$1.77. We find anomalously high Vp/Vs ratios at Harrat Lunayyir, interpreted as solidified magma intrusions. Slow shear-velocities in the upper-mantle lid throughout the southernmost and northernmost Arabian shield suggest lateral heating from hot mantle upwellings centered beneath Afar and (perhaps) Jordan.

Our findings on crustal S-velocity structures, Vp/Vs ratios, and upper-mantle lid velocities support the hypothesis of lateral mantle flow from the Afar and (perhaps) Jordan plumes as plausible sources for the Cenozoic volcanism. Additionally, observed surface volcanism and dyke intrusions in the western Arabia may be due to small-scale adiabatic ascent of magma diapirs. Our ongoing work using surface-wave tomography will provide new perspectives to image the velocity structure of Saudi Arabia and to build a coherent geodynamic framework for the Arabian plate and Red Sea tectonics.