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Lithospheric dynamics in eastern Mediterranean: Insights from seismic structure and anisotropy

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The slow convergence of the African, Arabian and Eurasian Plates in eastern Mediterranean has been accompanied by widespread deformation of continental lithosphere within the region. The continuing southward retreat of the Hellenic Trench, where oceanic lithosphere is subducting northward, is accommodated by lateral movements and stretching of continental blocks of the overriding plate. Both the boundary conditions and lateral variations in the mechanical strength of the lithosphere determine the distribution and character of the localised and diffuse deformation that is taking place.

Seismic velocities within the lithosphere depend on its temperature and can be used to infer its strength. Azimuthal seismic anisotropy indicates fabrics within the crust, mantle lithosphere and asthenosphere that are a record of their deformation and flow. Seismic observations can thus provide key information on the flow patterns and underlying mechanisms of the complex lithospheric deformation. Here we present the results of the analysis of surface waves recorded at seismic stations in eastern Mediterranean. Frequency-dependent surface-wave anisotropy reveals depth-dependent orientations of anisotropic fabrics in the crust and mantle. Isotropic-average shear-velocity profiles and surface-wave tomography indicate variability in temperature and, therefore, in mechanical strength of the lithosphere.

Published shear-wave splitting measurements show remarkably uniform, NNE-SSW fast-propagation orientations across much of eastern Mediterranean, suggesting large-scale flow within the asthenosphere towards the retreating Hellenic Trench. The motion and deformation of lithospheric blocks are also driven by the trench retreat but are very different from those of the asthenosphere beneath them. The character of deformation within the lithosphere varies laterally and, also, vertically, from the brittle upper crust to the ductile lower crust and lithospheric mantle.

The shear associated with the westward motion of Anatolia is localised at and near the North Anatolian Fault (NAF). Seismic-velocity profiles and upper-mantle tomography show that the lithosphere gets warmer and thinner from the Black Sea (north of NAF) to central Anatolia (south of NAF). This confirms that the fault is localised near the transition between the mechanically strong and weak lithospheric blocks. The ductile lower crust and mantle lithosphere beneath NAF show E-W, fault-parallel, distributed flow within an at least 100 km wide zone.

NAF extends westward into the warm, mechanically weak lithosphere of the Aegean Sea, where it splits into a series of NE-SW oriented faults. Right-lateral slip on these faults, combined with their counter-clockwise rotation and with some stretching, accommodate the overall N-S extension in the northern Aegean. (The extension is evidenced by gradients between GPS vectors and occurs in addition to the NE-SW translational motion of the entire south-central Aegean block.) This N-S extension takes place, also, in the mantle lithosphere of northern Aegean, but the deformation changes in character with depth. The stretching within the deep part of the lithospheric plate is accommodated by a simple, N-S viscous flow, evidenced by the N-S orientation of the anisotropic fabric in the northern Aegean mantle lithosphere.

The complex three-dimensional patterns of deformation in eastern Mediterranean are governed by three-dimensional variations in temperature and rheology. Seismic structure and anisotropy, together with geologic and geodetic data, reveal the patterns of lithospheric deformation and give us a glimpse into its fundamental mechanisms.