Western Tethys subduction history constrained through upper and lower mantle structure coupled to kinematic reconstruction

Derya Gürer¹,², Douwe J J van Hinsbergen¹, Douwe van der Meer²,³, and Wim Spakman²,⁴

¹University of Queensland, Faculty of Science, School of Earth and Environmental Sciences, St Lucia, Australia
²Department of Earth Sciences, Utrecht University, Utrecht, The Netherlands
³New Ventures Latin America, CNOOC International
⁴Centre for Earth Evolution and Dynamics, University of Oslo, Oslo, Norway

A current frontier in paleogeographic and geodynamic research is the reconstruction of the plate tectonic evolution of deep-time ocean basins. However, deep-time plate reconstructions of now-subducted ocean basins are challenging and often result in competing tectonic models, particularly when the upper plate was oceanic and is only preserved as ophiolitic relics. Correlations between paleogeography and tomographically imaged slab remnants has unlocked Earth’s modern mantle structure as an archive for the analysis of such deep-time geological processes. The geology of the western Tethyan realm from Greece to Oman in northeastern Arabia, holds records of the subsequent closure of the Paleo- and Neotethyan oceanic realms and of plates and microcontinents therein due to subduction since the Permian. Kinematic restorations reveal that the western Tethys contained at least three discrete plate systems bounded by transform faults, similar to the Atlantic Ocean today. Previous tomography-geology studies have interpreted the upper and lower mantle structure in terms of subduction history for the Aegean and Arabian segments, but particularly lower mantle structure of the Anatolian segment has not been resolved in detail before. In this segment, kinematic restorations have suggested that at least four subduction zones were responsible for the consumption of oceanic lithosphere, two consuming the Paleotethys, and two consuming the Neotethys. For the Neotethys system, slab segmentation may have led to more than two slab segments in the final mantle architecture. We here interpret the upper, and for the first-time, the lower mantle structure associated with the Anatolian segment, thereby unraveling western Tethys oceanic lithosphere lost to subduction since the Early Triassic, and link this to mantle structure and subduction evolution of the Aegean and Arabian segments. The modern mantle structure as imaged in the tomographic P-wave speed model UU-P07, tested against multi-model vote maps, provides means to find the relics of the complex subduction history and to discern between existing tectonic models. The tomographic model reveals ten major positive wave speed anomalies interpreted as slab remnants: the previously identified Aegean, Algerian, Emporios, Antalya, Egypt (which is part of the Arabian slabs), Cyprus, Mesopotamia, Al Jawf, and Zagros slabs, and the newly identified Pontide and Herodotus slabs, partly in the upper, but mostly in the lower mantle. We compare the dimensions, locations, and orientations of these slabs with the kinematically-restored subducted area of the Neotethys, and identify the deepest lower mantle anomalies (Emposios, Herodotus, Al
Jawf) as remnants of Paleotethys subduction of the three segments, and the remaining anomalies as the expression of complex Neotethys subduction, consistent with recent kinematic restorations of Eastern Mediterranean and Arabian orogenic history. Moreover, we confirm recent findings that the orientation of slabs influences their net sinking rate, with vertical slabs subducted at mantle-stationary trenches sinking faster than flat-lying slabs that once draped the mantle transition zone due to roll-back or trench advance.