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Slab dragging and the recent geodynamic evolution of the western Mediterranean plate boundary region

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The Tortonian-Present geodynamic evolution of the plate boundary between North Africa and Iberia is characterized by first-order enigmas. This concerns, e.g., the diffuse tectonic activity of the plate boundary; the crustal thickening below the Rif; the closing of the northern Moroccan marine gateways prior to the Messinian Salinity Crisis; crustal extension of the central to eastern Betics; the origin and sense of motion of the large left-lateral Trans Alboran Shear Zone (TASZ) and Eastern Betic Shear Zone (EBSZ); and lithosphere delamination of the North African continental edge. Many explanations have been given for each of these seemingly disparate tectonic features, which invariably have been addressed in the plate tectonic context of the NW-SE relative plate convergence between the major plates since the Tortonian, mostly independently from each other. Usually there is no clear role for the subducted slab underlying the region, except for presumed rollback, either to SW or to the W, depending on the type of observations that require explanation.

Here we integrate the dynamic role of the slab with the NW-SE relative plate convergence by 3-D numerical modelling of the slab evolution constrained by absolute plate motions (Chertova et al., JGR,2014 & Gcubed 2014). By combining observations and predictions from seismology, geology, and geodesy, with our numerical 3-D slab-mantle dynamics modelling, we developed a new and promising geodynamic framework that provides explanations of all noted tectonic enigmas in a coherent and connected way. From the Tortonian until today, we propose that mantle-resisted slab dragging combines with the NW-SE plate convergence across the (largely) unbroken plate boundary to drive the crustal deformation of the region.

Slab dragging is the lateral transport, pushing or pulling, of slab through the mantle by the absolute motion of the subducting plate (Chertova et al., Gcubed, 2014). Because the slab is connected to both the Iberian and African lithosphere, both plates are dragging the slab by their shared ∼NNE component of absolute plate motion, which in fact is invisible in the relative plate convergence frame that is usually adopted. Slab dragging induces mantle resistance that, we demonstrate by numerical modelling, leads in the region to differential lateral motion between the slab and African plate driving indentation of the Africa continental lithosphere leading to crustal shortening explaining the closure of Moroccan seaways and the thickening of the Rif crust. The differential motion also explains the TASZ and the transition from western Betics shortening to eastern Betics extension, both still active today. During Miocene westward slab rollback mantle-resisted slab dragging also provided the driving force of edge delamination of African lithosphere, we propose.

These explanations of geological features are fully corroborates by an analysis of the GPS motion field in terms of the strain- and rotation rate fields using the method of Spakman and Nyst (2002), and the predicted crustal flow field. In particular, we derive from the GPS and geological data that the direction of African absolute motion is ∼NNE and that the slab experiences at present negligible rollback.