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Reactivated lithospheric-scale discontinuities localize dynamic uplift of the Moroccan Atlas Mountains

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The Atlas Mountains of Morocco have received considerable attention in the past decade regarding the lithospheric structure and the uplift mechanisms of this structurally simple mountain belt. Miller and Becker (2014) have recently added to the discussion with new results from receiver functions and shear-wave splitting analysis. These results confirm the mantle upwelling hypothesis for the Atlas uplift that was postulated 10 years ago and we now see highlighted in several forums. The relationship between modest tectonic shortening and high topography in the Atlas was first addressed by Teixell et al. (2003). They concluded that crustal thickness is insufficient to account for the observed elevations, and proposed a mantle-driven (upwelling) component of uplift, supported by low seismic velocities in the Atlas mantle reported already by Seber et al. (1996). Subsequent efforts focused on modeling of gravity, the geoid, and topography that indicated a prominent lithospheric thinning, placing the lithosphere-asthenosphere boundary (LAB) at 70–90 km beneath the Atlas Mountains (e.g., Teixell et al., 2005; Zeyen et al., 2005; Missenard et al., 2006; Fullea et al., 2010). New contributions on the basis of active and passive seismology, partly under the Picasso project frame, are on their way (e.g., Bezada et al., 2013; Carbonell et al. 2013; Palomeras et al., 2013; Miller and Becker, 2014).

Miller and Becker present a receiver functions profile that also shows a thinned crust and lithosphere beneath the Atlas Mountains. However, the thinned domain is bounded by abrupt steps coinciding with the location of the South Atlas thrust front; the authors propose offsets of 9 km of the Moho and 26 km of the LAB across the boundary thrust fault at Errachidia (Miller and Becker, 2014, their figure 2), arguing for the important role of lithospheric-scale discontinuities in the Atlas mountain building. As for the crust, this is intriguing because early refraction studies by Wigger et al. (1992) and a more dense wide-angle survey by Carbonell et al. (2013) failed to detect a crustal step in this position, but especially because there is ample evidence that the South Atlas fault is a low-angle thrust zone (Saint Bezar et al. 1988; Teixell et al., 2003). Moreover, Miller and Becker imply that the same fault discontinuity goes down to offset the LAB, which means that the South Atlas thrust projects vertically to a depth of 90 km. This has doubtful geological sense even assuming that the present-day thrusts derive from the inversion of earlier extensional faults: those would also have a dip, and at a depth of 90 km they would be off the vertical projection of the fault surface exposure. Miller and Becker recognize that previous authors document shallowly dipping thrust faults from outcrop and seismic reflection studies, but they do not further discuss this issue. We are left questioning whether there is an enigmatic geological feature in the Atlas that escapes our understanding, or an issue of seismic data resolution.

Miller and Becker compare the detected position of the LAB with a modeled position on the basis of the residual topography and on the assumption of isostasy, resulting in a large discrepancy, as the modeled LAB is even shallower than the actual base of the crust. This indicates a strong contribution of dynamic topography due to active mantle upwelling. We do not question the validity of dynamic topography for the Atlas, but we miss a discussion of the earlier potential field models which, on the basis of isostatic equilibrium, fitted the residual topography and the geoid with a greater lithospheric thickness, which would be in accord with the new receiver function results (see references above).

Finally, we wish to conclude with a formal comment on the referencing to earlier work in the Atlas. Miller and Becker report a small orogenic shortening (15%–25%) inconsistent with Airy isostatic support and cite four papers, but none of them resulting in these small values of shortening nor do they address relationships between shortening and topography. Fullea et al. (2010) are not the primary reference for the distribution of Quaternary basalts, Frizon de Lamotte et al. (2009) do not provide cross sections to demonstrate shallowly dipping thrust faults, Sébrier et al. (2006) do not provide regional tomography models, and Beauchamp et al. (1999) do not suggest a mantle thermal anomaly as the source of volcanism in the Middle Atlas. Although these citations by Miller and Becker do not alter the main point of their paper, we wish to raise a word of caution for the persistence of incorrect citations.

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