

## Late Miocene Central Anatolian surface uplift and orographic rainout from stable hydrogen and oxygen isotope records

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A stable isotopic approach to surface uplift history of the S margin of the Central Anatolian Plateau (CAP), the second largest orogenic plateau in the Alpine-Himalayan belt, is the focus of this work. Extending at average elevations of 1 km and bordered by the 2-3 km-high Tauride Mts to the S, Mediterranean mantle dynamics have been instrumental in governing regional surface uplift [1], yet with detailed temporal and spatial patterns of surface uplift remaining conjectural. For the first time, we apply a paleoaltimetric approach to the CAP by (1) looking at stable hydrogen and oxygen isotope ratios of continental deposits (such as paleosol and lacustrine carbonates and hydrated volcanic glasses), taking advantage of their recent, precise age calibration based on chrono- and biostratigraphy, and (2) providing a robust template of stable hydrogen and oxygen isotopes from modern surface waters on the CAP and across the Tauride Mts, against which the continental proxy data can be validated. We show that integrity of the modern meteoric water data nicely images the present-day topographic structure of the CAP and the Tauride Mts, with ca. -24 ‰/km and -3 ‰/km isotopic lapse rates for  $\delta D$  and  $\delta^{18}O$ , respectively. We then compare two sets of  $\delta^{18}O$  data of fossil meteoric waters as recorded in proxy minerals from Upper Miocene to Quaternary deposits in front of the growing Tauride Mts and in its N rainshadow. The data reveal fairly uniform isoscapes at the S plateau margin until 6.3 Ma, with a major isotopic shift occurring between 8.2 and 5.5 Ma, with a  $\Delta(\delta^{18}O_{\text{windward-leeward}})$  of 3.4 to 5.6 ‰. This difference corresponds to ca. 50 to 75% of that of the present-day altitude effect on isotope fractionation across the Taurides. Combined with stratigraphic evidence from margin-capping shallow-marine deposits of 8.4 to 8.1 Ma age [1], and with basin subsidence history at the Tauride front revealing a major clastic influx at 5.5 Ma [2], we conclude that 1000 to 1500 m of surface uplift occurred in less than 2.7 Ma, pointing to notably high uplift rates of 0.4 to 0.6 mm/yr for the Taurides in the Tortonian to Messinian. Our data compare well to short-term Quaternary uplift rates on incised river terraces [3].

[1] Cosentino et al. (2012) *GSA Bull.* **124**, 133-145.

[2] Cipollari et al. (accepted) *GSL, Spec Publ.*

[3] Schildgen et al. (2012) *EPSL* **317-318**, 85-95.

## Evidence for distinct stages of magma evolution recorded in the composition of accessory phases and whole-rocks in silicic magmas

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Accessory minerals may contain a detailed record of the evolution of silicic magmas. Different stages of magma evolution are preserved in the trace element compositions of apatite inclusions and their host rocks in the normally zoned Criffell pluton, southern Scotland. Apatites in metaluminous outer zones define a trend of variable La (277 to 2677 ppm) and less variable Y (0 to 662 ppm) (trend 1), and lie on the same trend as that defined by the whole-rocks (WR) throughout the pluton. By contrast, apatites from peraluminous inner zones show variable Y (276 to 2677 ppm) and low La (<1079 ppm) (trend 2). WR isotopic and elemental trends have previously been modelled by assimilation and fractional crystallization (AFC) [1]. Zircon  $\delta^{18}O$  varies by more than 3‰ between zones, but zircons within individual zones (within which apatite is included) are mostly within analytical error (0.4‰  $2\sigma$ ) and thus show limited evidence for assimilation during crystallization of apatite and zircon. Crucially, in each metaluminous zone only the most primitive (La-rich) apatites crystallized from melts that closely match its WR composition. Both the WR and the most primitive apatites in each metaluminous zone therefore preserve liquidus compositions, and little open system fractionation occurred throughout the crystallization of accessory phases in these zones. Trend 2 reflects the effects of monazite crystallization in peraluminous zones that led to depletion of La in accessory phases that crystallized after monazite saturation. However, no WR compositions lie on trend 2, indicating that they were not influenced by monazite fractionation. Variations in apatite trace element concentrations within each zone therefore reflect the effects of *in situ* crystallization of allanite in metaluminous zones and monazite in peraluminous zones. The independently determined compositions of WR and apatites support numerical models for the existence of crustal hot zones in the formation of silicic magmas [2]. WR compositions are determined at depth while textural maturity and the compositions of accessory minerals such as apatite and zircon are largely determined at shallower depths by the presence or absence of other accessory phases during *in situ* crystallization of small melt batches.

[1] Stephens et al (1985) *Contributions to Mineralogy and Petrology* **89**, 226-238.

[2] Annen et al (2006) *Journal of Petrology* **47**, 505-539.