Paleoelevation changes associated with Miocene crustal extension, Death Valley, California

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Quantitative paleoelevation histories can help to explain both why and how widespread Cenozoic extension occurred in the Basin and Range Province of western North America. However, suitable study sites where paleoelevation proxies, well-constrained magnitudes of crustal extension, and the timing of that extension can all be reliably constrained have proven elusive. Recent work in the Death Valley region, one of the most highly extended portions of the Basin and Range province appears to resolve long-standing controversy over the magnitude of extension across the region, and to contrain the timing of extension to post-middle Miocene. These constraints, combined with clumped-isotope paleothermometry of lacustrine carbonates from basins that pre-date large-magnitude extension, provide new insight into the paleotopographic response to crustal thinning in the central Basin and Range.

The timing and magnitude of extension across the Death Valley region has been re-evaluated using U/Pb geochronology of detrital zircons in the middle Miocene Eagle Mountain Formation, located to the southeast of Death Valley. The Eagle Mountain Formation contains distinct clasts, > 1 m in diameter, of the Jurassic Hunter Mountain batholith, which outcrops ~90 km to the WNW, on the northwest side of Death Valley [*Niemi et al.*, 2001]. Hack's Law, relating drainage area to fluvial transport distance,is convolved with detrital zircon age analysis of fluvial sediment to quantitatively assess the fluvial transport distance of that sediment from its source by measuring the dilution of the distinct Jurassic age peak derived from the Hunter Mountain batholith. We demonstrate that the Eagle Mountain Formation contains >75% Early Jurassic detrital zircons. Given the modern areal extent of the Early Jurassic batholith from which these zircons were derived, fluvial transport of these sediments could not have exceeded 25 km, and was most likely less than 12 km (Fig. 1.) [*Niemi*, 2013]. This estimate of extension agrees, within uncertainties, with new tectonic reconstructions of the magnitude of extension across Death Valley [*Renik and Christie-Blick*, 2013], and confirms previous interpretations that >200% extension has occurred across central Death Valley since middle Miocene time [e.g. *Snow and Wernicke*, 2000; *Niemi et al.*, 2001].

Pre-extensional paleoelevations for the Death Valley region were constrained using clumped isotope (Δ_{47}) thermometry of lacustrine carbonates collected from pre-extensional sedimentary sections. Δ_{47}-derived MAAT estimates of ~17–24°C for lacustrine carbonates from the central Basin and Range and contemporaneous lacustrine carbonates from known near-sea-level paleoelevations in the southern Sierra Nevada Bena basin indicate that Middle Miocene paleoelevations in the Death Valley region were ≤ 1.5 km (Fig. 2). These fairly low paleoelevations are incompatible with pre-extensional crustal thicknesses > 52 km and indicate that mean elevation change throughout middle and late Miocene extension was minor (≤ 500m; Fig. 3). Together, these data suggest that lithospheric mass was not conserved during > 100% Neogene extension of the central Basin and Range, but was instead likely compensated by synextensional magmatic additions to the crust [*Lechler et al.*, 2013].

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Snow, J. K. and Wernicke, B. P., 2000, Cenozoic tectonism in the central Basin and Range: Magnitude, rate and distribution of upper crustal strain: American Journal of Science, v. 300, p. 659-719.

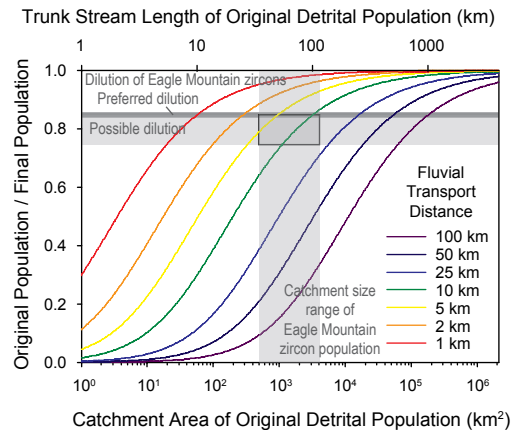

Figure 1. *Estimated fluvial transport distance (~10 km) of detrital zircons in the Miocene Eagle Mountain Formation from their source pluton ~90 km to the west-north-west.*

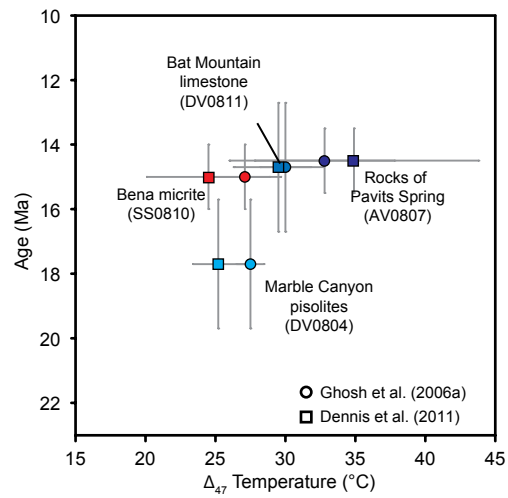

Figure 2. *Clumped isotope paleotemperature estimates for Miocene lacustrine micrites from sea level (Bena, western Sierra) and Death Valley (Bat Mountain Formation and Rocks of Pavits Spring) indicating similar paleoelevations.*

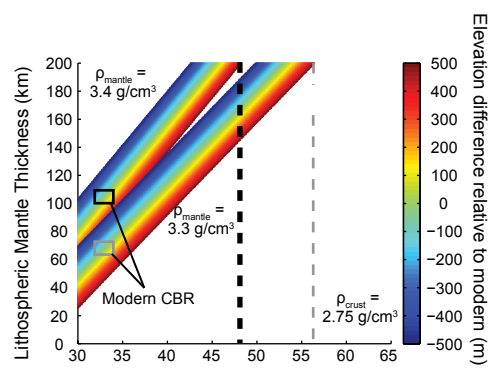

Figure 3. *Isostatic calculations of central Basin and Range (CBR) (paleo)elevations following the method of Schulte-Pelkum et al. [2011]. Colorbar shows calculated elevation values relative to modern mean CBR elevations of 1 km; the –500 to 500 m range equates to (paleo)elevations of 500 – 1500 m, which is the constrained paleoelevation range for Death Valley area based on carbonate Δ_{47} analysis.*