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Coupled basin-detachment systems as paleoaltimetry archives of the western North American Cordillera

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ABSTRACT

Stable isotope paleoaltimetry data from the Snake Range metamorphic core complex (MCC) and Sacramento Pass Basin (NV, USA) document that extensional mylonite zones and kinematically linked syntectonic basins reliably record paleotopography in the continental interior of western North America when compared to a sea-level reference. Here we show that this basin–MCC pair tracks meteoric fluid flow at different levels of actively extending crust in a high-topography region during Oligo-Miocene extension of the Basin and Range Province. For paleoaltimetry purposes we compare multi-proxy oxygen ($\delta^{18}O$) and hydrogen (δD) isotope data as well as geochronological information from the Snake Range MCC to a time-equivalent (ca. 20 Ma) stable isotopic proxy record from the Buckskin Mountains MCC (AZ, USA), which developed next to the Pacific Coast near Miocene sea level. We complement this paleoaltimetry study by comparing the Buckskin Mountains MCC data with older ($\sim$35 Ma) lacustrine stable isotope and paleofloral records from the nearby House Range (UT, USA), whose paleoelevation has been determined independently through paleobotanical analysis. Each of the investigated compartments of the paleohydrologic system within the Snake Range MCC depicts a coherent scenario of low Oligo-Miocene $\delta^{18}O$ and δD values of meteoric water that reflect precipitation sourced at high elevation. A 77‰ difference in δD_{water} between the Snake Range ($\delta D_{water} \sim -113$‰) and the Buckskin Mountains ($\delta D_{water} \sim -36$‰) is consistent with minimum mean paleoelevation of the Snake Range of about 3850 ± 650 m above Miocene sea level. Additional support for such elevations comes from a comparison between the Buckskin Mountains MCC and the Eocene House Range basin (UT, USA) where differences in $\delta^{18}O_{water}$ values are consistent with 2300 ± 500 m minimum paleoelevation of the House Range. Based on the presence of brecciated rock-avalanche deposits within the Sacramento Pass Basin, we conclude that the Snake Range was a topographic high and locus of significant relief during regional scale extension within the Cordilleran hinterland.

1. Introduction

The elevation of the Earth's surface is one of the most important characteristics of continental lithosphere and reflects the distribution of mass and heat inside the Earth, controls drainage patterns and detrital recycling, and influences atmospheric circulation and therefore precipitation and climate (e.g. Ruddiman and Kutzbach, 1989; Molnar and England, 1990). During the past decade stable isotope studies have reconstructed the paleoelevation of mountains belts. These studies exploit changes in meteoric water composition preserved in the geologic near surface record, using authigenic minerals from paleosol and paleolake deposits (e.g. Chamberlain et al., 1999; Garzione et al., 2000; Poage and Chamberlain, 2002; Horton et al., 2004; Garzione et al., 2006; Kent-Corson et al., 2006; Mulch et al., 2006, 2008; Rowley and Currie, 2006; Davis et al., 2009; Mix et al., 2011), or in deeper parts of the crust using silicates from extensional shear zones (Mulch et al., 2004, 2007).

The paleotopography of western North America has been a matter of debate, in particular since the advent of quantitative paleoaltimetry methods (e.g. Chamberlain et al., 1999; Poage and

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Chamberlain, 2001; Rowley and Currie, 2006; Rowley and Garzione, 2007). Abundant geologic and geochronologic evidence indicates that Cretaceous to Paleocene crustal shortening produced a welt of thickened continental crust that likely manifested itself in a high continental interior during and after the Sevier orogeny (Nevadaplano, DeCelles et al., 1995; DeCelles, 2004). Early Oligocene high elevations in the Cordilleran hinterland have been taken as evidence that late Mesozoic to early Cenozoic tectonics were responsible for a post-Sevier continental interior highland that subsequently collapsed to modern elevations (Gregory-Wodzicki, 1997; Wolfe et al. 1997; DeCelles, 2004).

Interestingly, a vast body of stable isotope paleoaltimetry data (e.g. Horton et al., 2004; Horton and Chamberlain, 2006; Kent-Corson et al., 2006; Davis et al., 2009; Mix et al., 2011; Chamberlain et al., in press) finds increasing evidence for extended dry continental highlands at about 49 Ma in British Columbia, Washington, and Montana, and ca. 40 Ma in central Nevada. Most of these paleoaltimetry studies use stable isotopic analyses of different terrestrial paleoclimate proxies from all over the orogen (Horton and Chamberlain, 2006; Mix et al., 2011; Chamberlain et al., in press). However, one major concern commonly observed is that each isotopic proxy material (lacustrine, palustrine, or pedogenic carbonates (Quade et al., 2007), authigenic and recrystallized silicates (Mulch and Chamberlain, 2007), or sedimentary or primary organic matter (e.g. Hren et al., 2010)) used as single-site stable isotope paleoaltimetry reconstructions have their individual biases when trying to reconstruct $\delta^{18}O$ or δD of precipitation from their isotopic composition.

Here we extend these approaches by combining multi-proxy, multi-isotope data from extensional mylonite zones and kinematically linked syntectonic basins that record paleotopographic and climatic changes during Cenozoic extension of the western North American Cordillera. We focus on the Snake Range metamorphic core complex (MCC) and Sacramento Pass Basin (NV, USA) (Fig. 1) that co-developed as a consequence of Oligo-Miocene extension of the Basin and Range Province. Collectively, this basin-core complex system provides an excellent opportunity to retrieve stable isotope data from different environments and levels of the crust, and tracks pathways of meteoric fluid flow from the critical zone at the biosphere–geosphere interface to the actively extending middle crust. We compare oxygen ($\delta^{18}O$) and hydrogen (δD) isotope ratios of mineral proxies from the high-topography region of the Snake Range in the continental interior to syntectonic minerals that crystallized at ~20 Ma during detachment activity of the Buckskin Mountains MCC (AZ, USA, Fig.1) that at the time was located close to the Pacific Coast near Miocene sea level.

The Snake Range and Buckskin Mountains represent classic examples of normal fault-bounded MCC. Even though detachments in both MCC are similar in age and in their role in shaping and

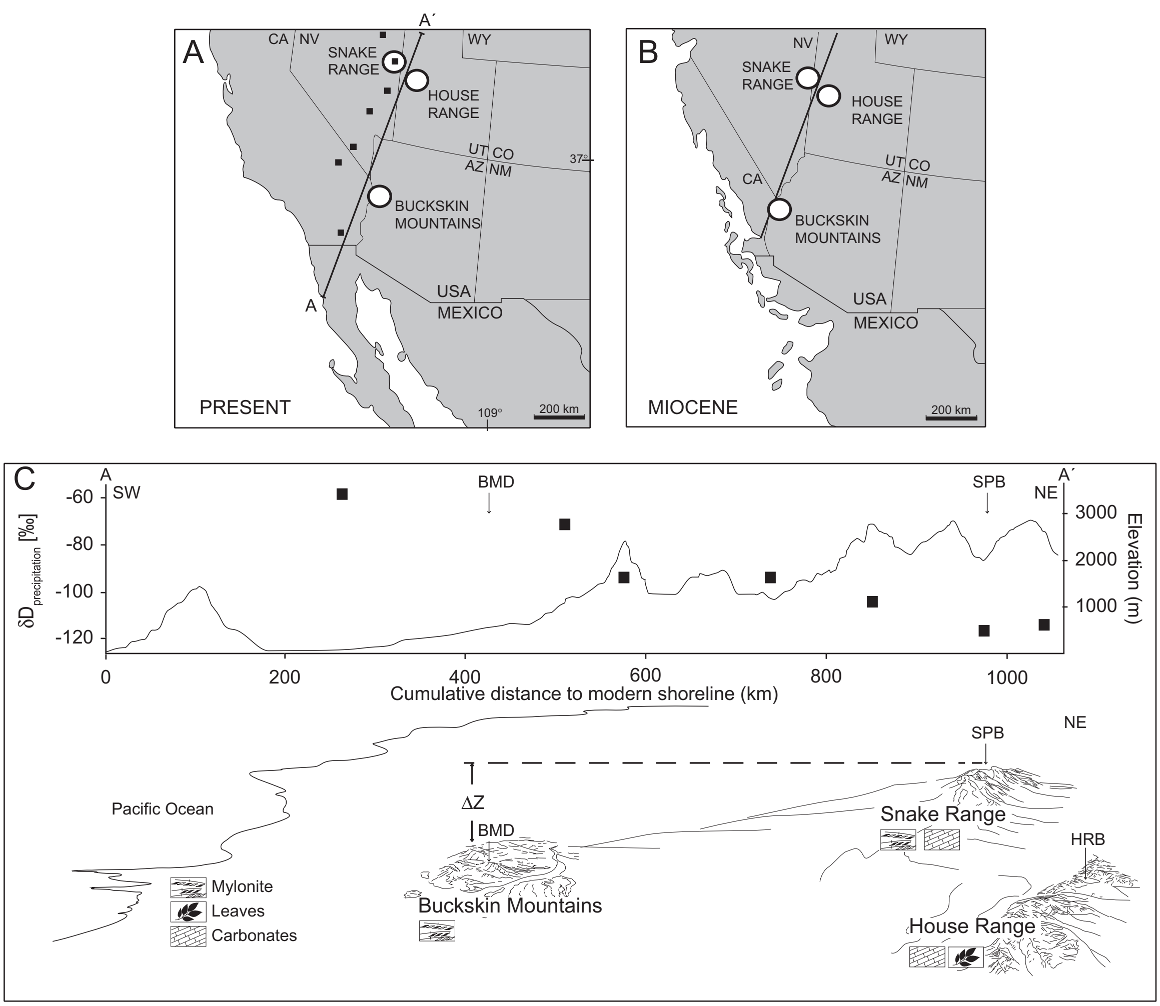

Fig. 1. Present-day (A) and Miocene Paleogeographic (B) Basin and Range Maps (after Blakey, 2011) showing position of the Snake Range, House Range, and Buckskin Mountains. Black dots in (A) are monitoring sites for isotopes in precipitation (Friedman et al., 2002b); corresponding $\delta D_{precipitation}$ values are shown in (C). (C) Present location of the Buckskin Mountains, Snake Range, and House Range along a NE–SW transect in the Basin and Range Province and their correlation with $\delta D_{precipitation}$. The black line indicates the topographic profile across the three different areas. BMD, Buckskin Mountains Detachment; SPB, Sacramento Pass Basin; HRB, House Range basin.