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Cenozoic topographic and climatic response to changing tectonic boundary conditions in Western North America

Malinda L. Kent-Corson, Laura S. Sherman, Andreas Mulch, C. Page Chamberlain *

Department of Geological and Environmental Sciences, Stanford University, Stanford, CA 94305-2115, USA

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Abstract

This study presents an oxygen isotopic record from the Paleocene to the Pliocene based on the analysis of predominantly paleosol carbonate from intermontane basins in southwestern Montana and eastern Idaho. $\delta^{18}O$ values of calcite decrease by 7 to 10‰ between ~50 and 47 Ma in southwestern Montana and Idaho most likely as a result of an increase in elevation of 2.5 to 3.5 km. This rise in elevation is roughly contemporaneous with the emplacement of the nearby Challis Volcanics, and the formation of metamorphic core complexes in the hinterland of the Sevier thrust belt. Moreover, when compared to previous oxygen isotopic studies that show oxygen isotopic shifts of similar magnitude occurring later (in the late Eocene to early Oligocene in northeastern Nevada, and late Oligocene to Miocene in southern Nevada), the results of this study add to a growing body of evidence for a spatial and temporal migration of high surface elevations from north to south in the Great Basin of western United States. This surface uplift history supports tectonic models calling for north to south removal of the Farallon slab or delamination of the mantle lithosphere.

Keywords: paleoaltimetry; Cenozoic climate; oxygen isotopes; Western United States Cordillera; paleosol

1. Introduction

During the past fifty years considerable effort has been directed towards using stable isotopes in paleoclimatic reconstructions. Much of what is currently known about the Earth's paleoclimate comes from stable isotopic compositions of carbonates collected from ocean drill cores. These ocean drill cores often provide high temporal resolution climatic records of the oceans, particularly for the Cenozoic [1]. Similar isotopic records for the continental interiors, however, are much more sparse. With the advent of stable isotope paleoaltimetry [2–4] there is now a concerted effort to collect stable isotopic records from intermontane basins worldwide. These studies not only provide information with regard to past elevations of mountain ranges, but also that of long-term terrestrial climate change. For example, there are now excellent oxygen isotopic records that extend from the Eocene to Recent in both the Tibetan/Himalayan orogen [3–9] and the North American Cordillera [10–16], as well as the Miocene to Pliocene Andes [17–19].

* Corresponding author. Tel.: +1 650 725 6835.
E-mail address: chamb@pangea.stanford.edu (C.P. Chamberlain).

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Continental climate records are likely to be far more complex than those from the oceans since the rise and fall of mountain ranges will influence atmospheric circulation patterns. It has been argued based on global climate models [20,21] that the construction of the major Cenozoic orogens, like the Tibetan Plateau and the western North American Cordillera, exerted a strong control on global and regional atmospheric circulation and precipitation patterns. Reorganization of atmospheric circulation patterns as a result of the rise of a major mountain range could cause the climate to vary spatially within an orogen. Indeed, different basins within the Tibetan region [c.f. 6,7,9] have distinct oxygen isotopic records that presumably reflect different climatic responses to the construction of the Tibetan Plateau. Thus, our understanding of how tectonics, topography, and climate of the continents are interrelated will require establishing stable isotopic records from multiple sites within an orogen.

Like Tibet, oxygen isotopic records from the North American Cordillera also differ between basins and along strike of the orogen. From the Miocene to Recent, oxygen isotope values of authigenic minerals increase by 2 to 8‰ in the central and northern Basin and Range [12,14,21], but decrease by 4 to 5‰ east of the Cascades [13,15]. Moreover, in the north-central Basin and Range province oxygen isotope values decrease by ~10‰ in the late Eocene to early Oligocene [14], but a similar decrease in oxygen isotope values is observed in the late Oligocene to Miocene in the south-central Basin and Range [16].

These oxygen isotope patterns have been interpreted to be the result of spatially and temporally varying topographic development of western North America. As such,

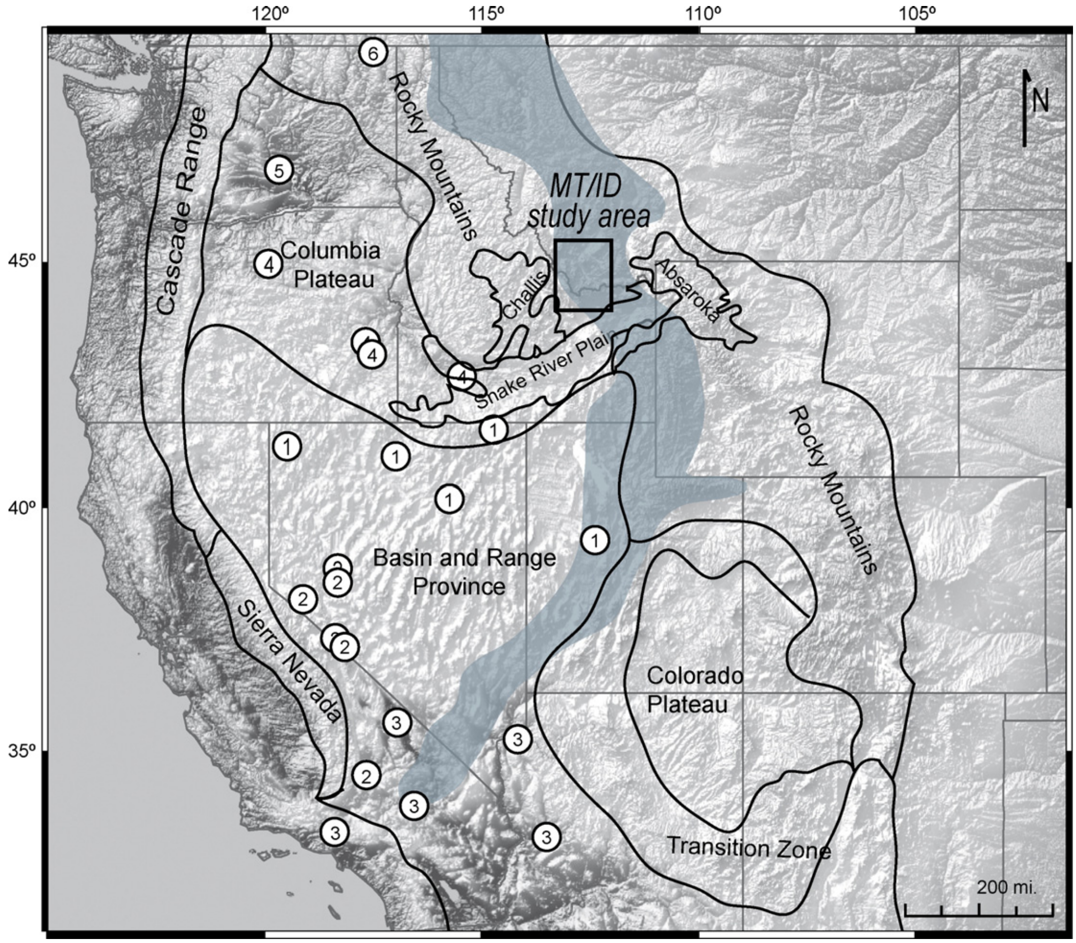

Fig. 1. Map of the western United States with Montana/Idaho sample localities enclosed by box. The locations of previously published stable isotope paleoaltimetry studies are indicated by numbered white circles: 1) Horton et al. [16]; 2) Poage and Chamberlain [14]; 3) Horton and Chamberlain [18]; 4) Kohn et al. [15]; 5) Takeuchi and Larson [17]; 6) Mulch et al. [21]. The Sevier fold-thrust belt is shaded in gray. Major physiographic features shown are adapted from USGS province maps and Dickinson [24].