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Geodynamic drivers of surface uplift, foreland basin formation, and Miocene aridity in the Peruvian central Andes

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The onset of Miocene hyperaridity along the central Andean Pacific coast has been attributed to the development of a high-elevation orographic barrier. Here we evaluate the timing, rate, loci, causes, and climatic impact of attainment of high elevations using H isotopic compositions of hydrated volcanic glasses benchmarked to modern stream water analyses, and foreland basin archives in southern Peru (13–17°S). Mean catchment elevations calculated from H isotopic compositions of modern water using a non-linear isotopic lapse rate successfully reproduce modern elevations with precision better than $\pm$ 500 m at one standard deviation. Based on this relationship, we reconstructed Neogene surface uplift patterns from regional trends in hydrated volcanic glass H isotopic compositions. Results suggest multiple lithospheric processes contemporaneously modified the locations and rates of surface uplift. Specifically, elevation rapidly increased by 2–2.5 km in the early and middle Miocene in the Western Cordillera and Altiplano, respectively; this pattern is consistent with foundering of mantle lithosphere via Rayleigh-Taylor instability. The Eastern Cordillera was slowly elevated by $\sim$2 km from the early to middle Miocene; this slower uplift rate is consistent with crustal shortening in the absence of significant lithospheric thickening. Neogene paleoelevation results are consistent with earlier Paleogene foreland basin development in the northernmost Peruvian Altiplano driven by flexural loading of the Western Cordillera, and subsequent eastward migration of foreland basin deposition. The variable spatial and temporal development of orography and associated basins across southern Peru is consistent with the early Miocene onset and middle Miocene intensification of hyperarid conditions along the central Andean Pacific coast.