# Paleoelevation and Geomorphic Constraints on the Late Miocene Rise of the Andes: Geodynamic Implications for the Growth of Orogenic Plateaus

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Paleoelevation and incision histories provide important constraints on the timing and magnitude of regional surface uplift of mountain belts that point to specific processes that led to surface uplift. The sedimentary record and stable isotopic compositions of carbonates deposited in the northern Altiplano are used to reconstruct late Miocene paleoenvironment and paleoelevation. Multiple elevation proxies including paleoleaf physiognomy, $\delta^{18}O$ paleoaltimetry, and $\Delta_{47}$ paleothermometry, indicate that the Altiplano had attained no more that ~1700 m of elevation between 11.3 Ma and 10.3 Ma. Both $\delta^{18}O$ paleoaltimetry and $\Delta_{47}$ paleothermometry show that the northern Altiplano was raised to its current elevation by ~6.8 Ma, suggesting that surface rise on the order of ~2.5 km to 3.5 km took place between ~10 and 7 Ma. Geomorphic constraints on the incision history of widespread, low-relief paleosurfaces on both the eastern and western flanks of the Andes also suggest that significant surface uplift has occurred since ~10 Ma over the entire width of the mountain belt and over at least 5° latitude. Widespread incision of both the eastern and western slopes began between ~10 to 6.5 Ma, and reconstruction of the relief in these drainage systems by stream profile analysis has been used to infer ~1 to 2 km of surface uplift of the flanks of the Andes. The paleotopographic evolution of the Andes is reconstructed over the late Miocene by combining geomorphic evidence with paleoelevation constraints. Evidence for regional surface uplift requires the removal of eclogitic lower crust and mantle lithosphere as the dominant geodynamic mechanism for raising the plateau. However, lower crustal shortening or lower crustal flow may also account for ~1 km of additional surface uplift of the Altiplano relative to the cordilleras. Regional surface uplift of the Andean plateau in the late Miocene predicts a decrease in the horizontal deviatoric stress in the plateau that is consistent with observations of upper crustal shortening and magmatism; shortening ceased across the plateau between 10 and 7 Ma, coincident with widespread ignimbrite eruptions. The combination of geodynamic processes that appear to have occurred in the Andes in late Miocene time, including removal of high density lower lithosphere and flow of low density middle-lower crust, are likely mechanisms for building broad, flat, high elevation plateaus in convergent tectonic settings.