Comment on "Rapid Uplift of the Altiplano Revealed Through 13C-18O Bonds in Paleosol Carbonates"
T. Sempere, *et al.*
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Comment on "Rapid Uplift of the Altiplano Revealed Through ^{13}C-^{18}O Bonds in Paleosol Carbonates"

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Based on stable isotope measurements, Ghosh *et al*. (Reports, 27 January 2006, p. 511) concluded that the Bolivian Altiplano uplifted 3 to 4 kilometers between ~10.3 and ~6.7 million years ago as a result of gravitational loss of dense lithosphere. This result stands at odds with current geological knowledge of the Central Andes, and we propose a test for the reliability of the paleoaltimetry method.

Ghosh *et al*. (*1*) reconstructed the elevation history of the Altiplano plateau in the Bolivian Andes using a thermometer based on the temperature-dependent binding rate of ^{13}C and ^{18}O isotopes in carbonate minerals. Their measurements indicate that the Altiplano lay between –400 and 0 m from 11.4 to 10.3 million years ago (Ma) and rose to its current altitude at an average rate of 1.03 ± 0.12 mm per year between ~10.3 and ~6.7 Ma. Ghosh *et al*. concluded that such a rapid uplift was likely to have been produced by gravitational loss of dense lithosphere to the asthenosphere (delamination), but this scenario disagrees with current geological knowledge of the Central Andes.

The idea that part of the Bolivian Altiplano was at or below sea level as late as ~11 Ma disagrees with the common view that Andean orogeny started in western Bolivia either ~26 Ma (*2*) or ~40 Ma (*3*, *4*), and with geomorphic evidence that the volcanic highlands west of the Altiplano were above 2000 m as early as 20 to 17 Ma (*5*). Furthermore, forearc strata document that these highlands underwent uplift between ~40 and 10 Ma (*6*). The fault-bounded Corque Basin displays high compacted sedimentation rates [970 m per million years (My) between 12 and 9 Ma (*7*), decreasing to 337 m/My between 9 and 6 Ma (*8*)] and can be seen as a pull-apart basin (*9*) whose surface was at a substantially lower altitude than surrounding highlands. Therefore, generalization of paleoaltitudes reconstructed in the basin (*1*) to the entire Altiplano may be inappropriate.

Ghosh *et al*. (*1*) argued that their proposed uplift history is consistent with paleobotanical evidence (*10*). However, the current paleoaltimetry method based on fossil leaf morphology systematically underestimates high altitudes (*11*). Therefore, Low Miocene paleoaltitudes reported for Andean Bolivia using this method (*10*) may also be underestimations and cannot be invoked to support the results in (*1*).

Crustal thickening in the Central Andes is widely believed to have been caused by tectonic shortening (*12*). On the contrary, Ghosh *et al*. (*1*) contend that this process is too slow to account for the rapid uplift of the Altiplano implied by their results. Instead the authors suggest crustal delamination, removal of dense lower crust and/or mantle lithosphere, as a more plausible mechanism. However, this process can only occur when the lower part of the lithosphere has become gravitationally unstable as a result of thickening (*13*). Delamination below the Altiplano (*1*) should thus have been a consequence of thickening. However, if the Corque Basin was indeed at or below sea level at ~11 Ma (*1*), the crust—which is now ~55 km thick (*14*)—had not been thickened by then. Because an unthickened crust implies an unthickened lithosphere, it is difficult to explain why the lower lithosphere would start to delaminate before thickening. Even if thickening of the Altiplano crust started at 10.3 Ma with simultaneous "slow" delamination, it is unclear what process triggered thickening at that time.

Can soil paleotemperatures, and hence paleoaltitudes, be securely deduced from isotope-geochemical measurements? Ghosh *et al*. (*1*) assumed that the carbonate nodules they analyzed were devoid of diagenetic signal, yet they reported one sample (04BL69) from the 10.3 to 11.4 Ma interval that yielded an apparent paleotemperature of 50.3° ± 4.9°C and acknowledged that this was likely due to cryptic recrystallization during burial. The samples from this interval were subject to minimum burial depths of between 2200 and 3400 m (*8*) and thus to temperatures of 60° to 90°C (adopting a conservative estimate of 30°C/km for the geothermal gradient). We believe it unlikely that only one sample was selectively affected by burial metamorphism and that samples above and below were not.

We propose a simple test to determine whether a burial heating component is indeed present in the geochemical signal. The ~11.4 to 5.8 Ma, ~3.5-km-thick section analyzed by Ghosh *et al*. (*1*) [and (*8*)] is only the uppermost part of the ≥12-km-thick (*15*), 55.5-Ma continental succession that crops out in the Corque syncline. A ~4.7-km-thick part of this succession, partly overlapping with the former (*1*, *8*), was reliably dated 14.5 to 9.0 Ma by magnetostratigraphy (*7*) and displays facies, including carbonate nodules, somewhat similar to the ~11.4 to 5.8 Ma succession. Collecting samples down-section and processing them by the method used by Ghosh *et al*. (*1*) would show whether apparent paleotemperatures keep growing down-section or not, and thus refute or validate their method.

Because isotopic resetting may occur during burial diagenesis of paleosol nodules, the geochemical methods used by Ghosh *et al*. (*1*) should have been robustly validated by thorough down-section sampling before drawing conclusions about the history and mechanisms of uplift in the Central Andes. If burial is proved to have modified the geochemical signal as we predict, the reported paleoaltitude estimates from at least the 11.4 to 10.3 Ma interval will need to be reevaluated and the rapid and late Andean uplift proposed by Ghosh *et al*. reconsidered.

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