Deformation of the western flank of the Andes at ~20–22°S: a contribution to the quantification of crustal shortening

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The Andes are the case example of an active Cordilleran-type orogen. It is generally admitted that, in the Bolivian Orocline (Central Andes at ~20°S), mountain-building started ~50–60 Myr ago, close to the subduction margin, and then propagated eastward. Though suggested by some early geological cross-sections, the structures sustaining the uplift of the western flank of the Altiplano have often been dismissed, and the most common view theorizes that the Andes grow only by east-vergent deformation along its eastern margin. However, recent studies emphasize the significant contribution of the West Andean front to mountain-building and crustal thickening, in particular at the latitude of Santiago de Chile (~33.5°S), and question the contribution of similar structures elsewhere along the Andes. Here, we focus on the western margin of the Altiplano at 20–22°S, in the Atacama desert of northern Chile. We present our results on the structure and kinematic evolution on two sites where the structures are well exposed. We combine mapping from high-resolution satellite images with field observations and numerical trishear forward modeling to provide quantitative constraints on the kinematic evolution of the western front of the Andes. Our results confirm two main structures: (1) a major west-vergent thrust placing Andean Paleozoic basement over Mesozoic strata, and (2) a west-vergent fold-and-thrust-belt deforming primarily Mesozoic units. Once restored, we estimate that both structures accommodate together at least ~6–9 km of shortening across the sole ~7–17 km-wide outcropping fold-and-thrust-belt. Further west, structures of this fold-and-thrust-belt are unconformably buried under much less deformed Cenozoic units, as revealed from seismic profiles. By comparing the scale of these buried structures to those investigated previously, we propose that the whole fold-and-thrust-belt has most probably absorbed at least ~15–20 km of shortening. The timing of the recorded main deformation can be bracketed sometime between ~68 and ~29 Ma – and possibly between ~68 and ~44 Ma – from dated deformed geological layers, with a subsequent significant slowing-down of shortening rates. This is in good agreement with preliminary modeling of apatite and zircon (U-Th)/He dates suggesting that basement exhumation by thrusting started by ~70–60 Ma, slowed down by ~50–40 Ma, and tended to cease by ~30–20 Ma. Minor shortening affecting the mid-late Cenozoic deposits indicates that deformation continued after ~29 Ma along the
western Andean fold-and-thrust-belt, but remained limited compared to the more intense deformation that occurred during the Paleogene. Altogether, the data presented here will provide a quantitative evaluation of the contribution of the western margin of the Altiplano plateau to mountain-building at this latitude, in particular at its earliest stages.