Dynamics of large-magnitude extension in the Whipple Mountains metamorphic core complex

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The Whipple Mountains metamorphic core complex in the Colorado River extensional corridor of the Basin and Range province in SE California is one of the world's prime examples of large-magnitude crustal extension that inspired many of the modern concepts of metamorphic core complex formation and low-angle detachment faulting. The Whipple detachment is characterized by >60km of displacement and brittle kinematic indicators record top-to-the-NE fault slip, which is consistent with the mylonitic footwall fabric and regional middle Tertiary extension direction. Critical aspects in the temporal exhumation pattern of the Whipple Mountains core complex and in particular the dyamic evolution of the Whipple detachment system, such as the spatial progression of strain localization, the formation of secondary and subsequent breakaways, and the interplay of multiple subparallel detachment faults remain poorly understood. We collected samples parallel to the movement vector of the Whipple Mountains detachment for detailed (U-Th)/He thermochronometry from thirty-two samples along a transect of ~25 km in slip direction to decipher the detailed cooling history to estimate the slip rate, monitor variations in the footwall cooling patterns, and to elucidate the dynamic evolution of the Whipple detachment fault system. Apatite (U-Th)/He (AHe) ages range from 26.6 ± 1.1 Ma to 13.7 ± 0.4 Ma, while zircon (U-Th)/He (ZHe) ages range from 46.8 ± 1.2 Ma to 13.6 ± 0.3 Ma, and exhibit a marked inflection point, constraining the onset of rapid exhumation at 21.5±1.0 Ma. (U-Th)/He ages below the inflection point smoothly decrease in down-dip direction, yielding apparent time-integrated fault slip rates of 4.3 ± 2.7 km/Myr (ZHe) and 5.8 ± 3.2 km/Myr (AHe), respectively. A detailed look reveals that AHe and ZHe ages fall into distinct repeated age-distance arrays that are best interpreted as structurally repeated slices that were transferred from the footwall to the hanging wall during progressive fault slip and exhumation. These data illustrate the proposed model of footwall to hanging wall transfer of incisement slices along the Whipple detachment and allows for a quantitative assessment of this structural process. The data demonstrate that the Whipple detachment is a complex system of detachments acting at different times and different structural levels. Furthermore, our new data have important implications for the estimation of fault-slip rates from thermochronometric data as failure to recognize the structural repetition of incisement slices due to insufficient sample density will lead to a systematic overestimation of fault slip rates.