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Low-temperature thermochronometric constraints on the timing and rate of unroofing of the Whipple Mountains metamorphic core complex, southern Basin and Range Province

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The Whipple Mountains metamorphic core complex is located in the Colorado River extensional corridor of the central portion of the Basin and Range province in SE California. It is one of the world's prime examples of large-magnitude crustal extension leading to exhumation of middle-crustal rocks and a classic locality that inspired many of the modern concepts of metamorphic core complex formation and low-angle detachment faulting. The Whipple Mountains detachment is characterized by $>$60km of displacement and brittle kinematic indicators record top-to-the-NE fault slip, which is consistent with mylonitic footwall fabric and regional middle Tertiary extension direction. Despite many excellent structural and kinematic studies of the exhumed footwall, critical aspects in the spatial and temporal evolution of the large-magnitude displacement history of the brittle Whipple Mountains detachment system remain largely unconstrained. In particular, the timing and rates of detachment faulting, the spatial progression of strain localization such as the formation of secondary and subsequent breakaways, and the interplay of multiple subparallel detachment faults, are poorly understood and prevent a more thorough understanding of the tectonic evolution of the Whipple Mountains detachment and its role in large-magnitude crustal and lithospheric attenuation. The extensive exposure of footwall rocks in slip direction in the Whipple Mountains and adjacent ranges to the SW presents an ideal opportunity to constrain the timing and rates of footwall exhumation using low-temperature thermochronometry. For this study, we collected samples parallel to the movement vector of the Whipple Mountains detachment for detailed apatite and zircon (U-Th)/He dating to decipher the detailed cooling history to estimate the slip rate and monitor variations in the footwall cooling patterns. We collected a total of thirty-two samples along a transect of $\sim$25 km in slip direction from Lake Havasu in the NW to Savahia Peak in the SW. The zircon (U-Th)/He ages (ZHe) range from 13.6 $\pm$ 0.3 Ma to 46.8 $\pm$ 1.2 Ma while the apatite (U-Th)/He ages (AHe) progress from 13.7 $\pm$ 0.4 Ma to 26.6 $\pm$ 1.1 Ma. The inverse slope of the spatial age trend in slip direction allow estimation of slip rates of 4.3 $\pm$ 2.7 km/Myr (ZHe) and 5.8 $\pm$ 3.2 km/Myr (AHe), respectively, during the middle Miocene. Furthermore, ZHe data from the SW corner of the Whipple Mountains core complex exhibit an exhumed fossil Partial Retention Zone (PRZ) and marked inflection point, constraining the onset of tectonic exhumation and slip at 21.5$\pm$1.0 Ma along the Whipple detachment. This same pattern is not recognized in the AHe data, since the exhumed Miocene fossil PRZ appears to be located farther to the SW, closer to the postulated initial breakaway. AHe ages from the NE corner of the core complex deviate from the generally observed data trend and might suggest a secondary breakaway or the progressive transfer of a footwall sliver to the hanging wall along sub-parallel detachments. These new data demonstrate that the Whipple detachment is a complex system of detachments acting at different times and structural levels and that the (U-Th)/He method provides powerful means to reconstruct such complexities.