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Fast cooling of normal-fault footwalls: rapid fault slip or thermal relaxation?

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Rapid rock exhumation in mountain belts is often associated with crustal-scale normal faulting during late-orogenic extension. The process of normal faulting advects hot footwall rocks towards the Earth's surface, which shifts isotherms upwards and increases the geothermal gradient. When faulting stops, this process is reversed and isotherms move downwards during thermal relaxation. Owing to these temporal changes of the geothermal gradient, it is not straightforward to derive the history of faulting from mineral cooling ages (Braun, 2016). Here, we combine thermochronological data with thermokinematic modeling to illustrate the importance of syntectonic heat advection and posttectonic thermal relaxation for a crustal-scale normal fault in the European Alps. The N-S trending Brenner fault defines the western margin of the Tauern Window and caused the exhumation of medium-grade metamorphic rocks during Miocene orogen-parallel extension of the Alps (Rosenberg & Garcia, 2011; Fügenschuh et al., 2012). We analyzed samples from a 2-km-thick crustal section, including a 1000-m-long drillcore. Zircon and apatite (U-Th)/He ages along this transect increase with elevation from ~8 to ~10 Ma and from ~7 to ~9 Ma, respectively, but differ by only ~1 Myr in individual samples. Thermokinematic modeling of the ages indicates that the Brenner fault became active 19 ± 2 Ma ago and caused 35 ± 10 km of crustal extension, which is consistent with independent geological constraints. The model results further suggest that the fault slipped at a total rate of 4.2 ± 0.9 km/Myr and became inactive 8.8 ± 0.4 Ma ago. Our findings demonstrate that both syntectonic heat advection and posttectonic thermal relaxation are responsible for the cooling pattern observed in the footwall of the Brenner normal fault.

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