Constraining the near-surface response to lithospheric reorientation: Structural thermochronology along AlpArray geophysical transects

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The shape of the present-day European Alps results from a complex tectonic and climatic history since the onset of convergence between the African and Eurasian plates. Low-temperature thermochronology data are a unique archive that can trace the cooling history of rocks back in time during exhumation from upper to middle crustal levels to Earth's surface. However, the precise mechanisms that led to cooling and exhumation are still debated. In this study, we investigated the potential for mantle processes, such as potential subducting slab break-off or slab reversal, to leave a fingerprint in the rock cooling record of the present-day surface along three key, north-south oriented geophysical transects: NFP-20E, TRANSALP and EASI. Along all transects, our zircon and apatite (U-Th)/He data reveal reset Neogene (and younger) cooling ages centred around core complexes such as the Lepontine Dome and the Tauern Window indicative of late exhumation during the Cenozoic Alpine orogeny. North and south of these complexes, the cooling ages become older, forming U-shaped age distributions around the reset centres. Thermal history reconstructions along TRANSALP confirm a conspicuous southward shift of cooling towards the Southern Alps approximately at the time of deep-seated exhumation of the Tauern Window driven by motion along the mid-crustal Tauern Ramp in the Mid-Miocene. Thermo-kinematic models along the transect confirm this southward shift of deformation and (i) reproduce the distribution of cooling ages and thermal history reconstructions, (ii) are consistent with the present-day structural geometry along the transect, (iii) and the observed surface heat flux. It is possible that rock cooling is primarily driven by rock displacement along active faults and less by climatic and/or mantle buoyancy forces, which are both not included in the applied modelling approach. Our comprehensive thermochronological analyses allow two interpretations concerning mantle processes: (i) Assuming a strong coupling between the subducting and overriding plate, hence, the applicability of doubly-vergent orogen kinematics, then the thermochronological data are most consistent with an ongoing reversal in continental subduction polarity. (ii) A high degree of decoupling would negate the possibility that mantle processes are archived in the thermochronological record.

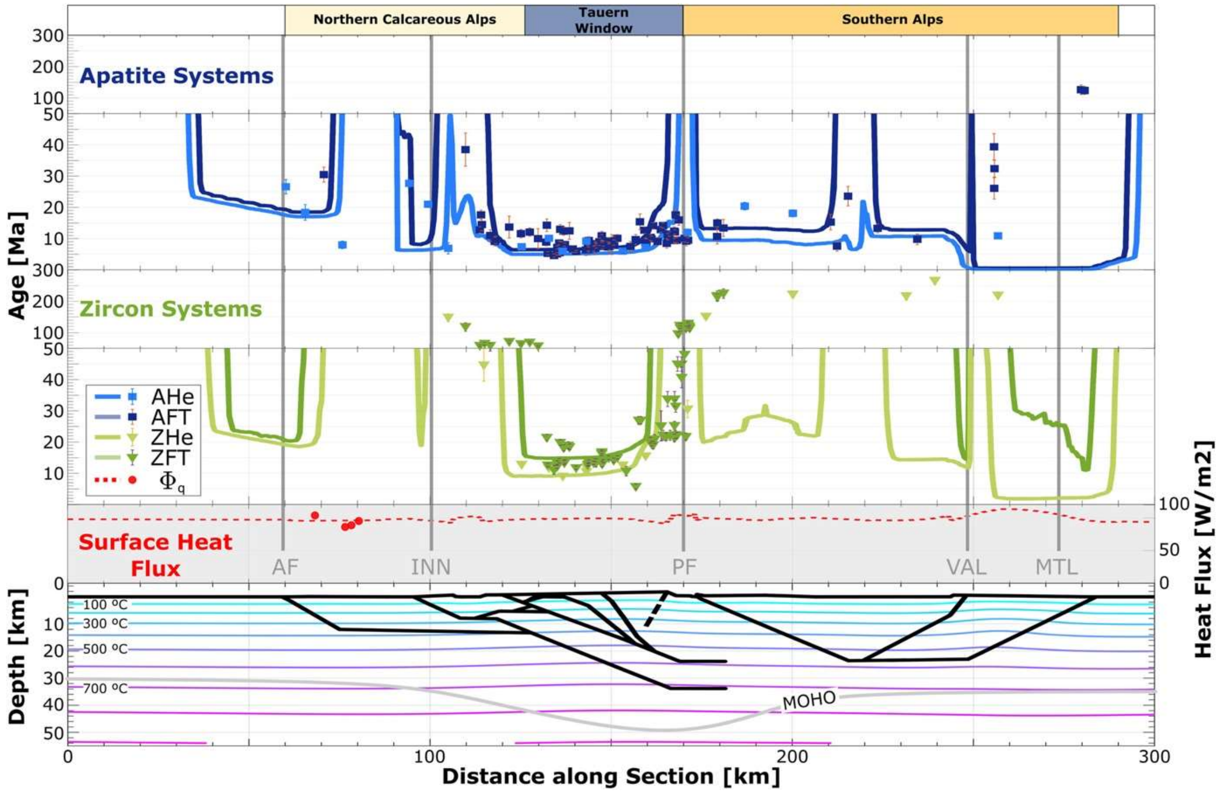

Figure 1: Forward thermo-kinematic model along the TRANSALP transect (Eizenhöfer et al., 2023). Predicted and measured present-day thermochronologic ages (solid lines and data points, respectively) for the apatite (AHe, AFT) and zircon (ZHe, ZFT) systems are shown in the top two panels (see also Eizenhöfer et al., 2021), predicted and observed heat flux in the third (dashed line and data points, respectively), shaded panel, the modeled thermal field based on an updated structural-kinematic reconstruction including modeled MOHO and tapered model topography on the bottom panel (no vertical exaggeration). AHe and ZHe, apatite and zircon (U-Th)/He; AFT and ZFT, apatite and zircon fission-track; Φq, heat flux [W/m2]. AT, Alpine Frontal Thrust; INN, Inntal fault; PF, Periadriatic Fault; VAL, Valsugana/Belluno thrust system; MTL, Montello thrust system.

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