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Warping of isotherms underneath topography: a combination of low temperature thermochronometers from the Malta Tunnel, Austria

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In determining exhumation histories using low temperature thermochronometers such as apatite (U-Th)/He and fission track dating it is often assumed that isotherms are flat. However, thermal models predict that shallow isotherms are perturbed by the overlying topography and if not accounted for, they can have a significant impact on thermal histories (e.g.,Braun, 2002; Foeken, 2004; Stüwe et al., 1994). If isotherms mimicking the surface topography occurs systematically, it can be exploited to provide hitherto unavailable information (e.g., House et al., 1998; Reiners et al., 2003). Until now the warping isotherms beneath topography has not been measured and it remains to be shown that geological factors such as heterogeneous heat production and loss and small-scale faulting in the shallow crust (or even analytical complications such as poor reproducibility of apatite (U-Th)/He (aHe) data) do not act to smear out the effects of topography. Here we present the results of a combined thermochronological and thermal modelling study aimed at identifying, and quantifying the effect of topographically modified isotherms underneath a rapidly denuding topography using apatite fission track and aHe of samples from the 20 km-long Malta tunnel in the Tauern Window in the Eastern Alps, Austria. The topographic wavelength of the Malta topography is 5-10 km, and is characterised by three main ridges. Samples from the tunnel are spaced approximately 1 km apart and are complemented by surface samples from the 1.5 km mountain range through which the tunnel passes. 2D-thermal modelling, using a denudation history derived from apatite fission track data, predicts

that aHe ages should vary systematically along the tunnel beyond the analytical uncertainty in the technique. The thermal model predicts distinct aHe age distributions depending on the time of incision of the topography, suggesting that the technique may prove to be a chronometer of topography. Apatite (U-Th)/He ages of surface samples along the northern segment of the transect yield ages between 15-10 Ma and show a positive age correlation with elevation. No clear age variation of surface samples along the southern segment is observed. AHe ages of the tunnel samples are generally younger ($\sim$7.5 Ma) underneath the topographic high in the central part of the tunnel and increase towards the outer parts of the tunnel (10-15 Ma). To a first order the obtained He ages support the predictions of the thermal models suggesting that warping of isotherms in natural settings does occur. However, the presence of tunnel samples that are older than age trend observed in the tunnel samples indicates that isotherm warping is not the sole contributor to age variation and that the shallow isotherms are possibly influenced by fluid flow and/or faulting. As predicted by the numerical models the apatite fission track ages do not show any significant variation in the tunnel, suggesting that, unless in cases where exhumation rates have been particularly high, the (U-Th)/He system is the most useful thermochronometer to detect warping of the isotherms.

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