

# Perturbation of isotherms below topography: constraints from tunnel transects through the Alps, Gotthard road tunnel

Poster

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## Introduction

For many years it has been known that near surface isotherms are influenced by the topography (Lees 1910). Recently, a number of studies were pursued to quantify the effect of topography on low temperature isotherms (e.g. Stüwe et al. 1994, Mancktelow & Grasemann 1997). The magnitude of perturbation depends on several parameters: exhumation rate, geothermal gradient, wavelength and amplitude of topography, and finally by the age of surface relief change (Braun 2002).

## Modelled perturbation

To obtain a rough impression of perturbation of near surface isotherms, a 2-D modelling approach following Stüwe & Hintermüller (2000) was applied to a profile intersecting the Aar and Gotthard massifs along the Gotthard road tunnel. Assuming steady state topography, wavelength of 20 km, a temporally and spatially constant exhumation rate of  $1 \text{ mm y}^{-1}$ , a geothermal gradient of  $20^\circ\text{C km}^{-1}$ , and height, slope and aspect dependent ground surface temperatures, the modelling results reveals significant perturbation of the near-surface isotherms (Fig. 1).

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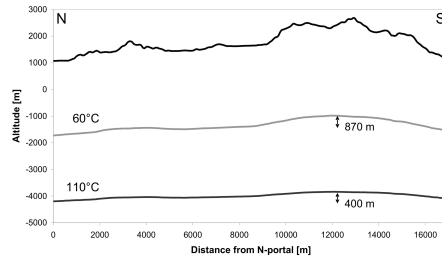


Figure 1: Results of 2-D modelling along the Gotthard road tunnel, showing the topography of the tunnel-transect, and the modelled  $60^\circ\text{C}$  and  $110^\circ\text{C}$  isotherms.

The modelled  $60^\circ\text{C}$  and  $110^\circ\text{C}$  isotherms are perturbed by 870 and 400 m respectively, suggesting that the isotherm-perturbation effect significantly influences the apatite fission track (AFT), and particularly the (U-Th)/He-system. To verify these modelled prediction, our study aims to directly measure perturbation of isotherms below topography by applying low-temperature thermochronology (zircon fission track, AFT and (U-Th)/He analysis). We therefore sampled three tunnel transects through the Alps (Gotthard and Mont Blanc road tunnels and Lötschberg railway tunnel), as well as their corresponding surface lines. The investigated regions are characterised by pronounced topography and rapid present-day surface uplift rates in the range of  $1 \text{ mm y}^{-1}$  (Kahle et al. 1997).

## Measure perturbation

AFT data from the literature (Schaer et al. 1975; Wagner et al. 1977) and own data were projected from within a corridor of 1 km along the tunnel-axis (Fig. 2). By linear interpolation of the AFT-ages, isochrones (here the 9, 8, 7 and 6.5 My isochrones) can be esti-

mated. The modelled isotherms (Fig. 1) and estimated isochrones (Fig. 2) show comparable perturbations correlating with topography. For palaeotopographic investigations the sample density has been increased along the tunnel transect. Currently, the AFT-age density is too low for palaeotopographic interpretations.

**Implications for age-elevation relationships (AER)**

Exhumation rates are routinely deduced from age-elevation relationships (i.e. from AFT-ages plotted *vs.* sample elevation). This approach, however, is based on the assumption of flat-lying isotherms. For perturbed isotherms, exhumation rates deviated from AERs are overestimated (Stüwe et al. 1994). Fig. 3a shows conventional AERs from the Gotthard and Aar massifs, yielding exhumation rates of 0.45 mm y<sup>-1</sup> and

0.54 mm y<sup>-1</sup>, respectively. Simplified 3-D modelling of the 110°C-isotherm, based on equations and input parameters mentioned above, yields modified AERs, plotted against the distance from present elevation to the modelled 110°C-isotherm (Fig. 3b).

In contrast to other correction approaches (e.g. Reiners et al. 2003), this procedure allows to correct every AFT-sample separately, accounting for their specific spatial topographic location. The resulting ‘real’ exhumation rates are about 10% lower than the apparent exhumation rates revealed from conventional AER, yielding 0.42 mm y<sup>-1</sup> for the Gotthard massif and 0.46 mm y<sup>-1</sup> for the Aar massif.

**Future investigations**

Samples collected from three tunnel systems and their corresponding surface traces will be analysed by AFT,

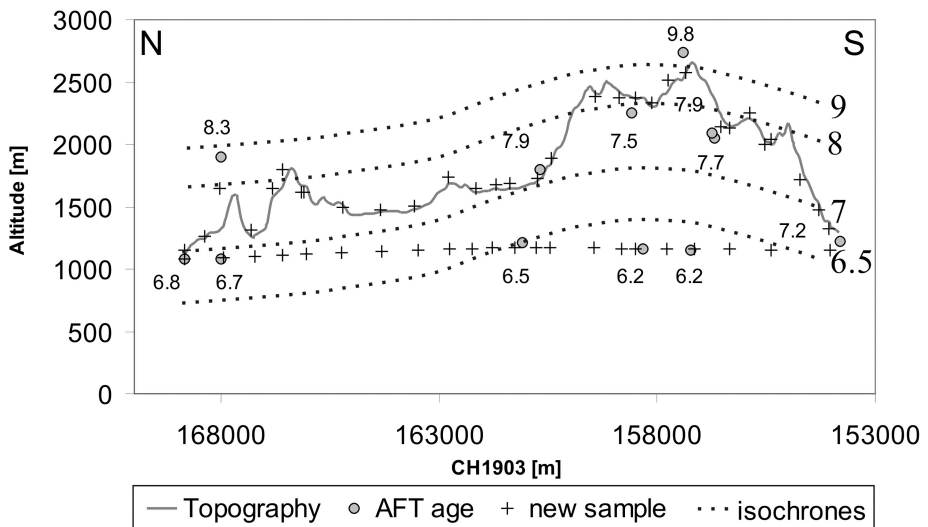


Figure 2: Sample pattern, available AFT-ages and interpolated isochrones along the Gotthard road tunnel transect.

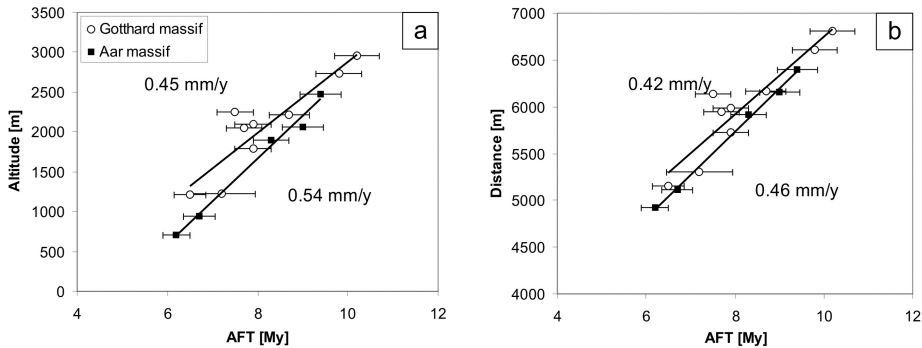


Figure 3: AFT-ages for the Gotthard and Aar massifs, plotted against their sampling altitude, yielding a clear age elevation relationship (a) and the same AFT-ages plotted against the distance from present elevation to the modelled 110°C-isotherm (b).

zircon fission track, and apatite (U-Th)/He thermochronology. This will allow to estimate the effect of isotherm-perturbation on these thermochronologic systems. The existing thermochronologic model will be refined, and different kind of models shall be tested for their consistency with the growing amount of low thermochronological data.

## References

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