Using the spread in apatite (U-Th)/He single grain ages to constrain the thermal history of the Northern Swiss Molasse Basin

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We use (U-Th)/He thermochronology on detrital apatite grains (AHe) to constrain the magnitude and long-term rates of exhumation of the northern Swiss Molasse Basin. Previous (mostly fission track) studies showed seemingly contradicting age patterns and resulting exhumation estimates (e.g., Mazurek et al., 2006; Cederbom et al., 2011). We hypothesize that this is because the sediments of the Molasse basin derived from different units in the Alps, as well as the Black Forest (Berger et al., 2005; Kuhlemann & Kempf, 2002). Consequently, the Molasse samples contain different populations originating from different source formations having different pre-Molasse temperature histories. Grains from successions below the Molasse Basin deposits (sandstones of Rotliegend and Buntsandstein sediments) possibly experienced additional heating and cooling events predating the formation of the Molasse Basin. As a result of the inherited thermal history, the grains do not resemble a single thermochronometer, but represent different thermochronometers, possibly sensitive to different closure temperatures. This variability of single grain ages can be exploited by dating a large number of grains distributed to a dense set of sampling intervals and performing statistical analysis on their age distribution and chemical parameters. Additionally, we focus on AHe thermochronology as it is sensitive to lower temperatures compared to fission track dating and is thus more suitable to cover the temperature history of the young and shallow Molasse samples.
A recently drilled Nagra borehole Bülach-1 provided the opportunity to carry out an intensive sampling along a 1370 m vertical section of the Molasse Basin. We divided the Molasse section (upper 500 m) into seven sampling intervals of which we dated in sum 45 grains from cutting samples. In comparison, previous studies used around 20 grains for fission track dating in only one or two intervals for the Molasse section (e.g., Mazurek et al., 2006; Cederbom et al., 2011).The drill cores of the successions below the Molasse sediments contain Buntsandstein and Rotliegend sandstones at the bottom 75 meters of the well. We divided these into three intervals, one represents the Buntsandstein and two the Rotliegend sediments. We dated in sum over 60 grains from these intervals.
The ages of the Molasse grains show a spread from 4 Ma to 30 Ma, while most of the grains have younger AHe ages compared to their depositional age. The Buntsandstein and Rotliegend grains show a spread in ages from 2 Ma to 80 Ma. First results from the age destribution indicate that at least two different

populations can be identified according to their initial ages and mineral chemistry within the Molasse sample set. The Buntsandstein and Rotliegend sample sets contain up to four different age populations. First estimates on the closure temperatures of the single thermochronometers based on helium concentration (following Shuster et al., 2006) vary between below 60 °C and over 80 °C, which consistently results in a first exhumation estimate of roughly 1050 to 1550 meters. Timing of exhumation is so far less well constrained. First results yield an exhumation phase starting at 12 to 13 Ma, with an end at 4 to 5 Ma.

This study reconciles previously seemingly conflicting estimates of exhumation estimates, and emphasizes the importance to separate different thermochronometers that coexist within a sample set. We show that dating a large number of single grains from a given sample offers the opportunity to statistically separate and characterize such different AHe thermochronometers.

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