Forum

Tracing exhumation and orogenic wedge dynamics in the European Alps with detrital thermochronology: COMMENT

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In a recent paper, Carrapa (2009) used low-temperature thermochronologic data of detrital grains from the pro- and retro-side foreland basins of the European Alps to determine when the two oppositely vergent wedges of the Alps were in subcritical or supercritical taper states. She used the lag time concept, where lag time is defined as the difference between the apparent fission-track (apatite, zircon) or ^{40}Ar-^{39}Ar (white mica) cooling age of a detrital grain and the depositional age of the grain in a foreland basin, to interpret the change of the taper states of the Alpine orogenic wedges through time. Carrapa found that shortening in lag time, and therefore an increase in the exhumation rate, supposedly represents a subcritical wedge, whereas an increase in lag time, or decrease in exhumation rate, represents a supercritical wedge.

While it is correct to use detrital thermochronology of orogenic sediments to trace exhumation of convergent mountain belts, the relationships between lag time and taper state of the European Alps, as presented by Carrapa, raise some interesting questions. For example, how sensitive are different thermochronometers to changes in taper state, or how is a change in taper state related to changes in rheology?

Carrapa presented information from different thermochronometers in the same lag-time plots, even if the closure temperatures of the different thermochronometers range from ~120 °C to >400 °C (see Reiners and Ehlers, 2005, and references therein). Each system has a different sensitivity to upper crustal processes, and the response times until all these thermochronometers adjust to changes in exhumation rates are considerably different. It may be better to discuss these data individually, rather then interpreting them identically, such as in Carrapa's figures 3A and 3B for the central-eastern Alps pro- and retro-side foreland basins. Interestingly, only lag-time trends of the youngest age peaks (fission-track) or grains (^{40}Ar/^{39}Ar) were used. The youngest peaks or grains are only representative of the fastest exhuming areas in the Alps, but not of the entire mountain belt. For determining the taper state of the Alpine wedges at different times, it may be better to use mean ages to follow average exhumation rates over time.

Unfortunately, not all available detrital thermochronological data were used for discussing changes in taper states. It may be worthwhile also considering detrital zircon fission-track data for the central-eastern Alps retro-side foreland basin of Bernet et al. (2009), here shown in Figure 1. The youngest age population of these zircons has a relatively constant lag time of about 8 m.y., which means that zircons were continuously exhumed by erosion and normal faulting in certain parts of the central Alps since the Oligocene. Carrapa argued that the central-eastern Alps changed from a supercritical to subcritical state, but this may not be compatible with constant exhumation of zircons for almost 30 m.y. In that respect, it would be helpful to have a clear interpretation for periods with steady lag-time trends. A steady lag-time trend of detrital zircon fission-track ages between 18 Ma and 8 Ma, shown in Carrapa's figure 3B for the western Alps pro-side foreland basin, is interpreted as representing a supercritical taper state, while a steady lag-time trend between 12 Ma and 0 Ma for the central-eastern Alps retro-side foreland basin is interpreted as a subcritical taper state. It would be interesting to know why these trends were interpreted differently. The static ^{40}Ar/^{39}Ar age of ca. 36 Ma observed in the western Alps retro-side foreland basin, shown in Carrapa's figure 3C, is first interpreted as a subcritical taper state, then as a supercritical taper state, and from ca. 12 Ma on, no interpretation is offered.

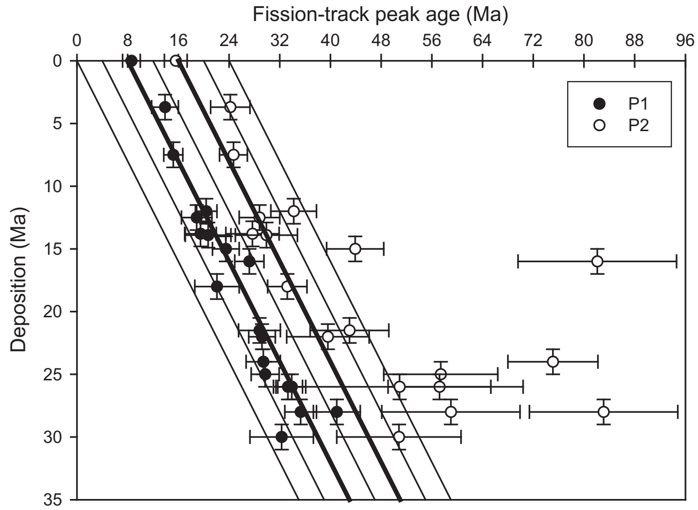

Figure 1. Lag-time plot of detrital zircon fission-track ages from the retro-side foreland basin of the Central European Alps. Shown are the two youngest grain-age components, P1 and P2, of each analyzed sample. The P1 ages indicate a constant lag time of about 8 m.y. over the past 30 m.y., while the P2 ages show some scatter, but have a relatively constant lag time of about 16 m.y. from 22 Ma to the present (modified from Bernet et al., 2009).

At last, Carrapa mentioned that a subcritical wedge is formed during rapid plate convergence and a supercritical wedge during slow plate convergence. Following this definition and the lag-time plots shown in Carrapa's figures 3C and 3D, the western Alps were converging faster than the central-eastern Alps for part of the Miocene, a somewhat surprising result. Moreover, Carrapa's figures 3A and 3D then imply that the convergence rate in the central-eastern Alps between 32 Ma and 12 Ma was different on both the pro- and retro-side of the orogen, and changed from slow to fast convergence. How is this possible? According to Schmid et al. (1997) north-south–directed convergence of the Eurasian and Adriatic plates between 35 Ma and 7 Ma was fairly steady at a rate of about 0.45–0.5 cm/yr.

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