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Exhumation pattern revealed by zircon and apatite (U-Th)/He thermochronology across a transpressional duplex: an example from the central southern Alborz mountains (N Iran)

Paolo Ballato (1), Daniel Stockli (2), Angela Landgraf (1), Manfred Strecker (1), Anke Friedrich (3), Mohammad Ghassemi (4), and Saeid Tabatabaei (5)

(1) University of Potsdam, Department of Geosciences, Potsdam, Germany (ballato@geo.uni-potsdam.de, landgraf@geo.uni-potsdam.de, strecker@geo.uni-potsdam.de), (2) Department of Geology, University of Kansas, Lawrence, Kansas, USA (stockli@ku.edu), (3) Department of Earth and Environmental Science, LMU Munich, Munich, Germany (friedrich@lmu.de), (4) Geological Survey of Iran, Tehran, Iran (m.r.ghassemi@gsi.ir), (5) Building and Housing Research Center, Tehran, Iran (htabatabaei@bhrc.ac.ir)

The Alborz mountains of N Iran constitute a sinuous, E-W oriented, double-verging orogen related to the Arabia-Eurasia continental collision. The range is located between the aseismic South Caspian Basin and Central Iran blocks. The central Alborz mountains have accommodated a significant fraction of the total plate convergence (ca. 50-60 km over 440 km in the last 20 Ma) and have been subjected to protracted exhumation (up to 10 km), which led to the development of mountain peaks exceeding 4.5 km of elevation.

The southern central part of the range is composed of a thick sequence (up to 8-10 km) of Eocene volcaniclastic sediments (55-36 Ma) forming a nascent south-verging transpressional duplex. This duplex system has accommodated long-term oblique shortening along: (1) NW-striking thrust faults (frontal ramps), which from NE to SW comprise the Mosha Fasham Fault central segments (MFFc), the Emamzadeh-Davoud Thrust (EDT), the Purkan-Vardij Thrust (PVT), and the north-west prolongation of the North Tehran Thrust (NTTw); and (2) E-W oriented left-lateral strike-slip faults (lateral and oblique ramps), including the Mosha Fasham Fault western segments (MFFw), possibly the Taleghan Fault (TF) along the northern margin of the duplex, the North Tehran Thrust (NTT), and the eastern Mosha Fasham Fault segments (MFFe) along the southern margin of the duplex. The NW-striking frontal ramps are cut by the NTT along the southern margin of the duplex, while along the northern margin fault linkage is incomplete.

Here we present new apatite and zircon (U-Th)/He data from different thrust sheets constituting the transpressional duplex in order to investigate exhumation patterns in such a complex structure and to understand the long-term coupling of tectonic exhumation and fault segmentation in an intracontinental mountain belt. The spatial distribution of zircon ages follows the geometry of the major faults with younger ages in the inner part of the duplex (18-16 Ma in the EDT hanging wall, and 20-30 Ma in the PVT hanging wall) and older ages along the margins of the duplex (39-47 Ma in both the NTTw hanging wall in the south-western margin, and the MFFc hanging wall in the north-eastern margin). Apatite cooling ages along the southern margin of the duplex (NTT hanging wall) have a different pattern, with cooling ages of 8-10 Ma at the eastern and western NTT terminations, and uniform ages of ca. 6 Ma in the central NTT segments, even across major frontal ramps such as the EDT and PVT.

Zircon cooling ages of 39-47 Ma at the duplex margins are interpreted to reflect volcanic cooling representing sediment depositional ages, which is in agreement with available geochronology data. Conversely, the 18-16 Ma ages are interpreted to reflect rapid cooling through the Zircon Helium Partial Retention Zone (ZHePRZ ca. 210-130 °C; closure temperature of 185°C) during enhanced rock uplift, while the 20-30 Ma ages represent slow cooling, and thus reproduce the fossil ZHePRZ. Apatite cooling ages of 10-6 Ma are interpreted to reflect rapid cooling through the Apatite Helium Partial Retention Zone (AHePRZ ca. 80-40°C; closure temperature of 65°C). The younger ages in the NTT central segments might reflect either a similar amount of exhumation along the NW-striking EDT and PVT frontal ramps, or a change in kinematics of the E-W striking NTT from an oblique/lateral ramp to a thrust fault. The lack in the NTT hanging wall of E-W striking structures refolding and/or offsetting the major NW-oriented frontal ramps and associated structures favours the first interpretation.

Taken together, our zircon and apatite data show that the greatest amount of exhumation occurred along the inner sectors of the transpressional duplex and decreased outwards. In particular, the EDT and the PVT exhumed at least 8-9 km and 5-7 km of rock units, respectively in the last 16-18 Ma, with a minimum of 2-3 km of exhumation at least since 6 Ma. Our data demonstrate how contractional deformation can be accommodated by complex structures through long-term fault segmentation producing differential exhumation. Additionally, this study highlights the importance of multiple thermochronometers in detecting such complexity.