Constraining the timing and duration of backthrusting in the Indus Group: a detrital zircon (U-Th)/He approach

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For the past few years, we have been investigating the low-temperature exhumation history of the syncollisional Indus Group in Ladakh, India. The Indus Group represents the first continentally derived sediment deposited after initiation of the Indo-Eurasian collision in this part of the orogenic system. Spectacular exposures of the Indus Group basin south of Leh, India, display a complex pattern of north-verging fold-and-fault systems that represent an important phase of backthrusting. However, the age of this event remains poorly constrained. The most generally accepted estimate is that of Searle and others (1990), who postulated an Early Miocene age for backthrusting and interpreted it as coincident in time with termination of Indus basin sedimentation. Based on apatite fission-track thermochronology on samples from the Zanskar Gorge, Clift and others (2002) suggested that backthrusting is younger, ~13-14 Ma. More recently, Kirstein and others (2009) proposed that pre-20 Ma backthrusting might be responsible for an important rotation of the Ladakh batholith north of the outcrop trace of the Indus Group.

Clift and others (2002) used illite-crystallinity measurements of Zanskar Gorge samples to demonstrate that parts of the sequence have been heated to >200°C, which slightly exceeds the nominal closure temperature for radiogenic He diffusion in zircon (~170-190°C; Reiners and others, 2004). Here, we exploit this epizonal metamorphism and use detrital zircon (U-Th)/He thermochronometry to examine the low-temperature thermal evolution recorded in the sandstones in the Gorge to constrain the timing and duration of reheating. In the absence of any field evidence for alternative heating mechanisms, we relate this reheating event to backthrusting.

In theory, if the heating event were sufficiently long in duration, the reset (U-Th)/He dates would allow us to constrain the age of metamorphism, and, by inference, the timing of backthrusting. In practice, the single-grain (U-Th)/He dates we obtained for 93 detrital zircon grains from the Zanskar Gorge ranged from 7.8±0.4 Ma to 39.0±1.1 Ma (2σ), implying that many grains are only partially reset. These findings establish the ages of at least some of the N-vergent backthrusts as Late-Miocene or younger.

Moreover, if we assume that the variable resetting resulted from a single thermal pulse related to backthrusting, the zircon data also provide an opportunity to further constrain the timing, as well as the duration, of the heating event. We focus here on a single sample (ZG-O) for which we have the most data (n=32) because it was collected from one of the >200°C locations of Clift and others (2002) and it corresponds to the location of a major backthrust structure. The dates from ZG-O range from 10.3±0.4 Ma to 21.7±1.2 Ma (2σ).

To estimate the duration of reheating (t), we use the equation for fractional loss (f):

$$f = 1 - (6/\pi^2)\sum_{n=1}^{\infty}[(1/n^2)\exp(-n^2\,\pi^2 Dt/\,r^2)]$$

where D is the diffusivity at a specific temperature (diffusivity data from Reiners and others, 2004), and r is the measured radius of each grain (McDougall and Harrison, 1998).

We assume that the youngest grain is fully reset (f = 0.99), and calculate the duration (t) of the reheating event that would cause complete resetting at 200°C. A duration of 2 my would fully reset many of the grains in ZG-O. If grain size and age were correlated, that would imply that the sample cooled slowly enough such that each grain had a slightly different closure temperature, which could explain the range of ages that we see. However, there is no correlation between grain size and age, which implies that even the youngest grain is not fully reset. As a consequence, we regard it as likely that the reheating event is younger than 10 Ma. Therefore, we postulate that the backthrusting responsible for reheating initiated at less than 10 Ma, and the duration of the event, or the maximum time that sample ZG-O was heated to 200°C, is less than 2 my. The lack of complete resetting of the (U-Th)/He zircon chronometer in these rocks implies a zircon resetting temperature, as defined by Gardés and Montel (2009), substantially in excess of 200°C for brief thermal events, consistent with our current understanding of He diffusion kinetics for zircon.

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