Geophysical Research Abstracts
Vol. 18, EGU2016-10264, 2016
EGU General Assembly 2016

Dating deformation - Lifetimes of phases vs. lifetimes of crystals and pulsed motion along fault zones

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The timing of movement in a fault zone may be obtained either by dating minerals that grow in these zones or by determining the pressure – temperature – time history of the blocks lying on either side of the zone. Interpreting dates of minerals in the fault zone itself requires the assumption that the minerals grew during or close to the timing of movement, that there was a single pulse of movement, or that the ages have not been reset by later pulses of movement. Determining the P-T-t history of the overlying and underlying blocks, on the other hand, may provide a more comprehensive history but it is essential to determine exactly what stage of a P-T history is dated by a given isotopic system. In addition, information on lateral contiguity is missing from such data. Strengths and weaknesses of both approaches may be illustrated using a case study from the MCT zone in the Sikkim Himalaya. Lu-Hf dates of garnets from the underlying lesser Himalayan (LH) and overlying higher Himalayan (HH) rocks yield a systematic picture (Anczkiewicz et al., 2015), but the significance of these dates using the same isotopic system and same mineral are different in the two blocks. In the lower grade lesser Himalayan rocks, fractionated trace element patterns formed during growth of garnet are preserved. As a result, bulk of the Lu occurs at the cores of garnets and the well-defined ages mark the initiation of garnet growth along the prograde path rather than the peak of metamorphism in these rocks. In the higher grade HH rocks, although metamorphic temperatures were higher (750 – 800 °C) they did not cross the closure temperature of Lu and/or Hf diffusion in garnet. In these pelitic bulk compositions, growth of garnet is expected to have occurred at garnet grade conditions ($\sim$ 500 °C). Nevertheless, in the presence of melt and deformation, there is evidence that the garnet grains recrystallized and Lu was more homogeneously distributed within the grain. Therefore, the ages from these rocks are the ages of peak of metamorphism in the presence of melt, rather than from the prograde path. When these information are combined with those from phase equilibria and geospeedometry, a systematic P-T-t history of the rocks may be constructed and as a result, a history of pulsed motion along the MCT may be obtained. Dates of rocks from the MCT zone itself, on the other hand, preserve one point in the P-T-t evolution. It can be shown that different isotopic systems (e.g. Lu-Hf in garnet vs. U-Th-Pb in monazites or zircons) preserve dates from different stages of this pulsed history and interpolating linearly between them to obtain rates of motion may give misleading results. Combination of both kinds of information with proper attention to the P-T history of the rocks yields the most internally consistent picture of motion along the fault zone.

Ref: Anzckiewicz, R., Chakraborty, S., Dasgupta, S., Mukhopadhyay, D., Koltonik, K.: Timing, duration and inversion of prograde Barrovian metamorphism constrained by high resolution Lu-Hf garnet dating: A case study from the Sikkim Himalaya, NE India; Earth and Planetary Science Letters, Volume 407, Pages 70 – 81, DOI: 10.1016/j.eps1.2014.09.035