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Argon geochronology used to unravel the effects of extreme extension in the Alpine, Aegean and Himalayan orogens during the closure of Tethys

Marnie Forster and Gordon Lister
Earth Dynamics, RSES, ANU, Canberra, Australia

Here we demonstrate the remarkable capacity of temperature-controlled furnace-step-heating $^{40}Ar/^{39}Ar$ geochronology, using the diffusional release of ^{39}Ar during such experiments to produce Arrhenius data, and then inverting these data to constrain the temperature-time history in and adjacent to geological structures. The issue we address is how to objectively determine the tectonic significance of large-scale ductile shear zones. The critical factors are the timing, and whether or not it is possible to demonstrate that a particular shear zone accomplished crustal extension, or the reverse. It is not easy to determine the significance of major structures without data as to the temporal variation of temperature that was caused by their operation. The geodynamics of Tethyan collisions cause thrusting to be followed by subsequent episodes of extension, so it is not possible to ascertain the nature of individual structures based on differences in metamorphic grade across them. The accretion process involves material on the subducting plate sliced free by the megathrust, and stacked above in individual tectonic slices that eventually define the characteristic tectonometamorphic stratigraphy of the over-riding orogen. Tectonic slices successively accrete to the terrane stack as convergence goes on. Successive events thus also affect the terrane stack. It can be shortened: pre-existing tectonic slices can fold, often recumbently, or pre-existing thrusts can be reactivated, further dissecting the terrane stack. The terrane stack can be distended: extensional shear zones form that transect recumbent fold trains, and produce geometries that mimic Alpine fold nappes. Distension of the terrane stack can also lead to pre-existing thrusts being reactivated as detachment faults, and again, because the locus of fault movement is not precisely constrained to follow pre-existing structure, the terrane stack is further dissected.

$^{40}Ar/^{39}Ar$ geochronology when combined with ^{39}Ar diffusion experiments allows quantitative estimates of the variation of temperature with time across individual large structures, allowing resolution of these ambiguities. We are able to thereby document evidence for extensional ductile shear zones, along argon traverses in the Alps, in the Aegean, and in the Himalaya. The large variation of diffusional retentivity present in the average potassium feldspar allows a considerable range of temperature-time behaviour to be constrained, thus linking observations made using metamorphic petrology (at temperatures up to 600°C) with low temperature (U–Th)/He thermochronology and apatite and zircon fission track analyses. The simulation software allows the effects of solid state diffusion, as well as episodes of recrystallization and grain growth, to be taken into account.