Ar–Ar constraints on erosional versus extensional unroofing in orogenic belts: the Zanskar Himalaya, NW India

D. Vance
S. Kelley

Department of Earth Sciences, Open University, Milton Keynes MK7 6AA, UK.

Introduction

It is becoming increasingly recognised that late orogenic crustal extension plays an important role in the unroofing of regional metamorphic terrains. The results of numerical modelling show that such extension is often a normal consequence of overthickening of the continental lithosphere (England and Houseman 1988) and field studies have demonstrated the existence of large-scale extensional structures in the Alps and the Himlalaya (eg. Mancktelow 1992; Herren 1987). In the Himalaya, a large extensional structure (South Tibetan Detachment Zone) is observed along the the entire mountain range and has been recognised as a major influence on the thermal structure of the crust in the late stages of the orogeny (eg. Herren *op. cit.*). The cooling rates of metamorphic rocks in such regions are likely to be the result of an interplay between normal erosional unroofing and the effect of tectonic removal of overburden, as well as cooling in response to the emplacement of cool upper crustal rocks directly on top of the hot middle and lower crust. In this contribution, we report the results of measurements made on muscovite and biotite from the Zanskar Himalaya, NW India using the laser argon microprobe with the aim of elucidating the relative importance of these two processes in orogenic belts.

The Zanskar Himalaya expose a Barrovian metamorphic sequence of metapelites and meta-amphibolites in the hanging wall of the Main Central Thrust. The isograds define a dome elongated east-west with sill-K-feldspar grade rocks in the core and gt-bio grade rocks on the periphery (Kundig 1989). High temperatures in the core have led to extensive crustal melting and the production of migmatites and leucogranites. To the north the isograds are truncated and telescoped against a north-dipping normal fault, the Zanskar Shear Zone, such that the horizontal distance betweeen the sill-K-feldspar and ga-bio

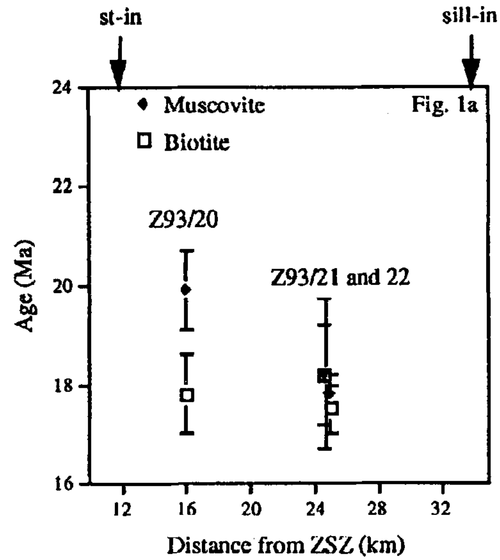

FIG. 1a.

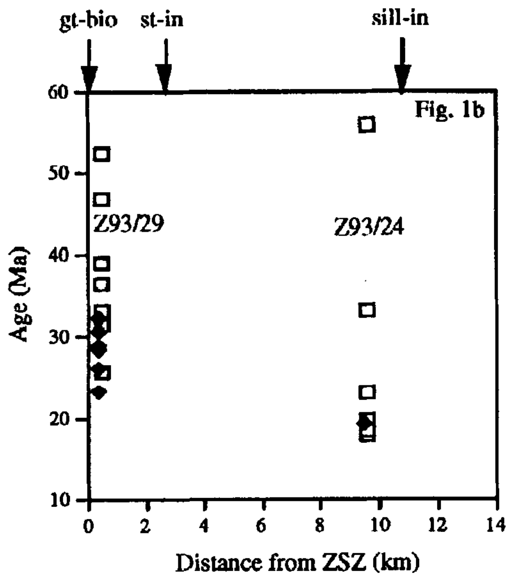

FIG. 1b.

isograds is as little as 3km. In contrast, to the west the isograds are less truncated so that this distance is up to 48km.

Results

Argon data on samples from two traverses, representing sections where the isograds have been telescoped to differing degrees, are displayed in Fig. 1. All points are the averages of 6-8 laser spots except in the case of the biotite analyses for Z93/24 and both muscovite and biotite analyses in the case of Z93/29 where the results for each spot are shown.

The first-order observation is that all the muscovite and biotite ages (excluding those due to excess argon - see below), from a wide variety of grades, strongly cluster around 20–17Ma. The results, therefore, reproduce the phase of early Miocene cooling seen elsewhere along the Himalayan chain (eg. Harrison *et al.*, 1992). Secondly, the maximum age difference between the muscovite and biotite ages is 2.1Ma implying that these rocks cooled at a rate of at least 50°C Ma^{-1}. The age of the peak of metamorphism is as yet poorly constrained but a single zircon age of 22Ma has been obtained from a granite (M.P. Searle pers. comm.). Taken along with the present data, this gives a period of 2–4Ma for cooling between ~700°C and muscovite closure and thus cooling rates in excess of 90°C Ma^{-1}.

More detailed scrutiny of the results yields the following observations.

1. For the traverse across the the less telescoped isograds, lower grade rocks display both earlier and slower cooling. For example, sample Z93/20 went through the muscovite closure temperature at 20Ma and the biotite T_c at 17.8Ma. In contrast, Z93/21, from near the sillimanite isograd has identical muscovite and biotite ages of 17.8 and 17.5 Ma respectively, implying both faster and later cooling than Z93/20.

2. Biotites (Z93/24) and both muscovite and biotite analyses (Z93/29) from the traverse showing greater telescoping of isograds contain excess argon (Fig. 1b), presumably due to fluid infiltration during shearing. Core-rim traverses across large biotites from these rocks should yield constraints on the timescale for the addition of this excess argon and thus that of fault movement. Even if one assumes that the youngest biotite age for Z93/24 is representative of the real age, the muscovite and biotite ages are identical (18.8 ± 0.8Ma and 17.9 ± 0.9Ma respectively) and imply cooling very fast and later than the lower grade samples from the western traverse but approximately synchronous with the higher grade samples from that area.

Discussion

Our interpretation of the above data is that the effect of the normal fault has been superimposed on normal erosional exhumation and cooling. The lower grade rocks from the western traverse show the earliest and slowest cooling, consistent with erosional exhumation. We suggest that the fault had not yet moved when these rocks were cooling through the muscovite closure temperature or, more correctly, its thermal effect had not propagated this far. The higher grade rocks from this traverse, on the other hand, show later and very fast cooling (eg. Z93/21 and Z93/22). By the time these more deeply buried rocks were cooling through the muscovite and biotite closure temperatures, the thermal effect of the fault had propagated this far. Numerical models show that more deeply buried rocks should cool more slowly. The fact that these cool faster than the lower grade rocks must reflect the effect of the normal fault on the thermal structure of the crust at this time. By contrast, where the isograds are more telescoped, and therefore where normal faulting has cut out large amounts of the section, all grades cool fast and late. The coincidence of biotite ages from all samples from all grades at ~17.5–18Ma probably means that the fault moved at around this time. Taking a thermal diffusivity (κ) of $1 \times 10^{-6} m^2 s^{-1}$, the time required for the thermal effect of the fault to propogate as far as sample Z93/21 (l = 17.5km normal to the fault) is about 10Ma (l^2/κ) whereas the effect seems to have been felt instantaneously in that this sample has the same biotite age as those closer to the fault. This latter observation would seem to imply some faster mode of heat transport than conduction.

References

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