Cosmogenic ^{3}He accumulation in alluvial garnets in bedload from Central Nepal rivers: Implications for cosmic-ray exposure dating of Himalayan erosional processes

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Cosmogenic isotopes, such as ^{3}He, ^{10}Be, ^{26}Al, are continuously producted at the Earth's surface in rocks and soils by cosmic ray spallation of light isotopes, providing a powerful tool for dating young geomorphological processes. The datation method based on the accumulation of cosmogenic ^{3}He is particulary appealing because: ^3He_c (where suffix c refers to ^{3}He produced by cosmic rays) is a stable isotope, its production rate is high and its natural background is very low. Moreover, its analysis is sensitive, relatively simple and rapid. However, the applicability of this method is limited by the high diffusivity of ^{3}He. In practice, ^3He_c is quantitatively retained in olivine phenocrysts, allowing datation of young basaltic flows. Dunaï and Roselieb (1996) have argued that the diffusivity of helium is lower in garnet than in olivine. The use of garnet for ^3He_c dating presents the interesting advantage to extend the field of this method to crustal metamorphic domains, and therefore to the case of major orogens.

We have measured^3He_c in alluvial garnets sampled in bedload from Central Nepal rivers (Fig. 1). They represent 3 different monolithologic catchments. By analysing fractions of several tenths of grains, we integer the complex history of each individual grain and the results obtained are mostly meaningful for comparison between different positions in a river basin. The garnets were formed in gneisses of the High Himalaya Crystalline (HHC) and schists of the Lesser Himalaya (LH) during high grade metamorphism resulting from the Main Central Thrusting (MCT) during Miocene. In this system, uplift rates estimated using the Ar/Ar method on micas, feldspars and monazite in garnet are high between 2 and 4 mm/yr depending on the position with regard to the MCT (Copeland *et al.*, 1991).

For ^3He_c dating purpose, pyropes and almandines are more appropriate than grossularites et spessartites (Dunaï and Roselieb, 1996). Electron probe analysis showed that the mean composition of the garnets was Alm. 70%, Pyr. 15%, Gros. 7%, Spes. 5%, Andr. 3% except for sample MO38 wich showed a larger contribution of the grossular end-member (Alm. 54%, Pyr. 12%, Gros. 26%, Spes. 6%, Andr. 2%). Helium was extracted using a CO_2 laser from mg-sized pure garnet fractions and its amount and isotopic ratio measured with a high sensitivity rare gas mass spectrometer in Nancy ($S_{He} = 3.5 \times 10^{-4}$ A/Torr, He blank $= 2 \times 10^{-15}$ mol). Helium-3 present in minerals is the sum of the following potential contributions: $^3He_t = {}^3He_c + {}^3He_a + {}^3He_n + {}^3He_m$ (where suffixes t, a, n and m refer to total, atmospheric, nucleogenic, and mantle-derived). The parent rocks of metamorphic garnets are thought to be marine sediments, mostly turbidites, which makes the possible contribution of mantle-derived ^3He_m unlikely. In agreement with that, He isotopic ratios measured in hot springs along the MCT are show typical radiogenic values (Marty *et al.*, 1996). ^3He_a was estimated from the measured ^{20}Ne content. The contribution of nucleogenic ^{3}He in garnet, produced by activation of Li by natural thermal neutrons, was computed from ion probe analysis of Li in garnet and from U and Th analysis of garnets (ICP-MS), or from estimate of U, Th content of parent rocks. In all cases the atmospheric and nucleogenic ^{3}He contributions were found to be small with respect to the total ^{3}He content of the samples.

Time exposure duration and erosion rate

Since the cosmogenic nuclide production rate increases by approx. a factor of 2.2 per 1000 m from a sea-level rate estimated at 85 atoms ^3He_c/g.yr at the Nepal latitude (e.g. Lal, 1991), the computed exposure age depends critically on the inferred elevation where exposure took place. The problem is not serious for most samples since alluvial sands were recovered at altitudes close to the mean elevation of the respective catchments. In one case

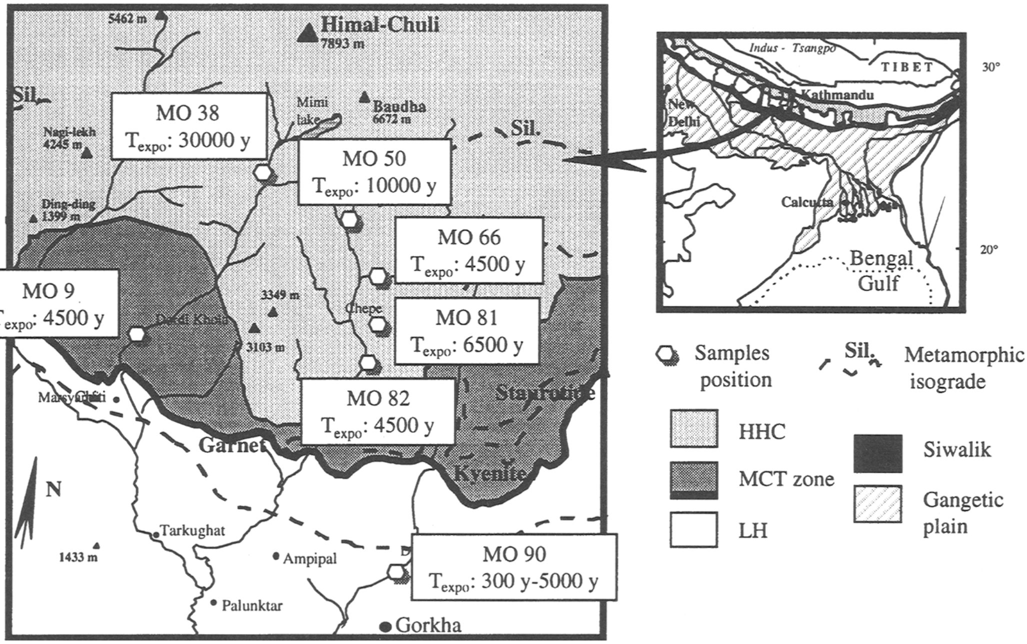

FIG . 1. Samples situations and average time exposure.

however (MO 90), the sampling altitude (550 m) was very different from the mean elevation of the corresponding catchment (~ 3000 m), leading to considerable uncertainty in the computed exposure age. The corresponding age range (Fig. 1) is lower than those of samples recovered at higher altitude, suggesting that sands now sampled at lower elevation were transported or eroded more rapidly than those stored in the upper bassin areas. The resulting exposure durations are within 5,000–10,000 yr (Fig. 1), leading to computed erosion rates ($\varepsilon = 1/[J.T_{expo}]$,where J = coefficient of mass attenuation - 160 g cm^{-2} - and T_{expo} = exposure duration; Lal, 1991) of the order of a mm/yr, in qualitative agreement with exhumation rates (Copeland *et al.*, 1991). One sample (MO38) shows higher exposure duration, and it is not clear if this excess is due to the different composition of garnet (with the possibility of underevaluating the ^3He_c production rate in grossularites; Dunai and Roselieb, 1996), or to its occurence near a crest which might imply longer exposure history.

With respects to existing exposure dating methods, that based on ^3He_c accumulation in garnets is extremely sensitive. Given the level of analytical blanks (2000 atoms ^{3}He), it should be possible to address durations of the order of 10 yr for one gram sample. However the natural background of ^{3}He is garnets sets a lower limit of the order of $10^2 - 10^3$ yr.

References

Copeland *et al.* (1991) *J. Geophys. Res.*, **96**, 8475–500.

Dunaï, T.J. and Roselieb, K. (1996) *Earth Planet. Sci. Lett.*, **139**, 441–21.

Kurz, M.D. (1986) *Geochim. Cosmochim. Acta,* **50**, 2855–62.

Lal, D. (1991) *Earth Planet. Sci. Lett.*, **104**, 424–39.

Marty, B. *et al.* (1996) *11th Himalaya-Karakorum-Tibet Workshop Abstr.*, 97–8, Flagstaff.