Quantifying denudation rates with vertical relief fission track profiles

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Apatite fission track analysis can identify differential vertical movements of the crust by recording the cooling that results from the denudation that is caused by tectonic uplift, by local relief changes or by changing climate. This can be most tightly constrained and quantified if vertical relief profiles are available. The full potential of vertical relief profiles is achieved if the palaeogeothermal gradient and denudation rates are calculated directly from these profiles.

Knowledge of the palaeogeothermal gradient is crucial for further quantification of the denudation history (i.e. converting palaeotemperature information into palaeodepth information). The magnitude and timing of denudation can be directly derived if modelling techniques are applied, and information about the palaeogeothermal gradient can be extracted.

When samples are collected from an undisrupted vertical relief profile, the resulting data can be modelled to produce an internally consistent thermal history. The palaeogeothermal gradient at a certain time can be reconstructed by plotting the maximum palaeotemperature versus present elevation of the sample. The gradient of this slope displays the palaeogeothermal gradient at that particular time. The gradient of a linear slope between apparent fission track age, and elevation provides a direct estimate of the denudation rate over this time interval.

Due to the excellent exposure of the Brandberg Igneous Complex, the highest mountain in Namibia with 2573 m, we can provide the first empirical estimates of the palaeogeothermal gradient in this region, which is a key parameter for the calculation of amounts of denudation from thermochronologic data. A palaeogeothermal gradient of approximately 27°C/km was determined to have prevailed in central Namibia in the Late Cretaceous. The net amount of denudation calculated using the geothermal gradient information is about five kilometres for the Brandberg region. An independent measure of the denudation rate between 80-60 Ma ranges in the order of 120 m/my..

Careful analysis of apatite fission track data provides detailed information of the exact timing and magnitude of crustal cooling. For Namibia, a phase of rapid cooling in the Late Cretaceous was triggered by a global change in spreading geometry, evident in other areas within Africa and the conjugated margin in South America too.

Combining information from vertical relief profiles and regional time-temperature information derived by thermal modelling of fission track data, long-term denudation models can be constructed and are also shown here.

The composition of Mid Atlas lithospheric mantle

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The metasomatic events which modified the geochemical signatures of the subcontinental lithospheric mantle beneath Ibalrhatene (Mid Atlas, Morocco) have been reconstructed by means of a combined EMP+LA-ICP-MS study of ultramafic xenoliths enclosed in the Plio-Quaternary alkaline basalts.

The collected xenoliths are characterised by a large compositional and textural variability. Amphibole (≥3%)-bearing, spinel peridotites show porphyroblastic textures; whereas amphibole (≤1%)-poor spinel peridotites have protogranular to porphyroclastic textures. Wehrlites are medium to coarse-equigranular; spinel (±garnet) websterites have granular to coarse–granular textures, and clinopyroxenite/ hornblendite samples show cumulus textures. Poikiloblastic texture has been found only in one composite harzburgite/wehrlite xenolith.

Most lherzolites have clinopyroxenes (Type 1) with REE patterns from slightly LREE-depleted (La_N/Yb_N~0.6) to LREE-enriched (spoon-shaped: La_N/Yb_N=1.3–17.2); cpx from harzburgites and a few lherzolite samples possess more strongly fractionated REE patterns (La_N/Yb_N up to 32.8, Type 2). Cpx from websterites, clinopyroxenite and orthopyroxene-free wehrlites (Type 3) display LREE/MREE-enriched upward-convex patterns (La_N/Yb_N=1.5–6.8). Cpx from the harzburgite/wehrlite composite xenolith are richer in REE than Type 2 & 3, and show upward-convex patterns (Type 4).

The different geochemical features of cpx can be ascribed to migration of successive and different metasomatic agents. Type 1 & 2 can be ascribed to a unique event related to the migration of alkaline melts fractionated by reactive porous flow through the lithosphere. The abundance of large orthopyroxene porphyroblasts in the peridotites suggests interaction with SiO_2-saturated melts. Type 3 samples are probably related to the successive magmatic venue of relatively undifferentiated, SiO_2-undersaturated magmas, probably circulating through magmatic conduits. Metasomatism operated by either a carbonate melt or CO_2-H_2O rich fluids is documented by Type 4 samp.

Preliminary Sr-Nd isotopic results on cpx show an overall homogeneity of the compositions in the different groups of samples.