The role of apatite fission track analysis (AFTA®) in constraining denudation histories.

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Apatite fission track analysis (AFTA®) provides direct constraints on key aspects of the thermal history experienced by any apatite-bearing rock and forms an essential element of any study of denudation history. The technique has found widespread use in the petroleum industry due to its ability to provide accurate information on the timing and magnitude of maximum paleotemperatures of sediment sequences. Vitrinite reflectance data provide complementary estimates of maximum paleotemperature and when integrated with AFTA from vertical sequences of samples (e.g. borehole or elevation profile), this approach allows quantitative determination of the timing and magnitude of the paleogeothermal gradient, and hence paleo-heat flow, at the time of maximum paleotemperatures (and perhaps in later events as well). It is the latter strength which gives AFTA the potential to provide a framework for quantitative assessment of denudation histories. It is essential to constrain paleogeothermal gradient both spatially and temporally in order to provide any meaningful constraints on the denudation history of a region. The assumption of time-invariant heat flow is not valid.

Even with a well-constrained thermal history framework, numerous assumptions are required to progress to quantitative and realistic estimates of denudation. Assuming that direct constraints on the paleogeothermal gradient can be obtained, the principal assumption required is the thermal conductivity of eroded section, but this cannot be known with any great certainty. In sedimentary basins this issue can be at least partially addressed by integration of parameters which are a more direct consequence of deeper burial such as shale density. This problem is particularly acute when working in basement terrains, where the section eroded might be any combination of highly conductive basement rocks, or generally less conductive sediments, which themselves can have highly variable conductivities. In addition, it is important to keep in mind the influence of the interpretive approach on the likely outcome. For example, the entire thermal history (or denudation history) cannot be fully defined by thermochronology, and assuming a monotonic cooling model can produce very different results from an approach based on episodic heating and cooling.

Most reliable results are obtained using a combination of different paleo-thermal methods plus methods such as those based on compaction estimates from sonic velocity data etc. Examples from Australia, Scandinavia, the UK and USA illustrate how an integrated approach using AFTA, VR and compaction data can provide a rigorous thermochronological framework for interpreting denudation histories.