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Apatite (U-Th-Sm)/He age dispersion arising from analysis of variable grain sizes and broken crystals - examples from the Scottish Southern Uplands

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Apatite (U-Th-Sm)/He (AHe) thermochronometry is a powerful technique for deciphering denudation of the uppermost crust. However, the age dispersion of single grains from the same rock is typical, and this hampers establishing accurate thermal histories when low grain numbers are analysed. Dispersion arising from the analysis of broken crystal fragments[1] has been proposed as an important cause of age dispersion, along with grain size and radiation damage. A new tool, Helfrag[2], allows constraints to be placed on the low temperature history derived from the analysis of apatite crystal fragments. However, the age dispersion model has not been fully tested on natural samples yet. We have performed AHe analysis of multiple (n = 20–25) grains from four rock samples from the Scottish Southern Uplands, which were subjected to the same exhumation episodes, although, the amount of exhumation varied between the localities. This is evident from the range of AFT ages ($\sim$60 to $\sim$200 Ma) and variable thermal histories showing either strong, moderate and no support for a rapid cooling event at $\sim$60 Ma. Different apatite size and fragment geometry were analysed in order to maximise age dispersion. In general, the age dispersion increases with increasing AFT age (from 47% to 127%), consistent with the prediction from the fragmentation model. Thermal histories obtained using Helfrag were compared with those obtained by standard codes based on the spherical approximation. In one case, the Helfrag model was capable of resolving the higher complexity of the thermal history of the rock, constraining several heating/cooling events that are not predicted by the standard models, but are in good agreement with the regional geology. In other cases, the thermal histories are similar for both Helfrag and standard models and the age predictions for the Helfrag are only slightly better than for standard model, implying that the grain size has the dominant role in generating the age dispersion. Rather than suggesting that grain size is the predominant factor in controlling age dispersion in all data sets, our results may be linked to the actual size of the picked grains; for grain widths smaller than 100 μm, the He profile within the crystal may not be differentiated enough to produce a dispersion measureable outside the uncertainty associated with the age. It is also easier for long-thin and short-thick than long-thick and short-thin grains to be preserved; this minimises the age dispersion that can be generated from fragmentation. We suggest, that in order to obtain valuable information from both fragmentation and grain size >20 large (width >100 μm) grain fragments of variable length have to be analyzed, together with a few smaller grains. Our results point to a strategy that favours multiple single-grain AHe ages determinations on carefully selected samples, with good quality apatite crystals of variable dimensions rather than fewer determinations on many samples.

[1] Brown, R. et al. 2013.Geochim. Cosmochim. Acta.122, 478-497
[2] Beucher, R. et al. 2013.Geochim. Cosmochim. Acta. 120, 395-416.