Geophysical Research Abstracts
Vol. 15, EGU2013-5838, 2013
EGU General Assembly 2013

Less is probably not more, anymore. Revisiting grain selection and analytical strategy for applying the apatite (U-Th)/He thermochronometry technique

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Common practice in the (U-Th)/He technique is to look for clear inclusion-free grains with euhedral, idiomorphic shapes whenever this is possible. As the diffusion domain size is the physical grain itself, picking a range of grain sizes will help to constrain the T-t modeling of the measured apparent ages. For identical grains, expected reproducibility is circa 10%, or for any grain if the sample cooled rapidly and therefore could be expected to yield discrete geological 'age'. However, even with very careful picking of individual grains it is not uncommon for ages from a single sample to be 'over-dispersed'. Using 'diagnostic plots' where apparent ages are plotted against grain-size or effective eU, one can look for positive correlations and use this as a basis for inferring grain-size or radiation damage effects as the cause of the observed dispersion. However, such diagnostic plots often show complex relationships and sometimes negative correlations which are difficult to interpret. We show that another major source of dispersion arises from the fact that the analyzed grains are usually broken during the mineral separation process. If so, complex behaviors including negative correlation between grain size and apparent ages are a natural consequence of the fragmentation effect, and that this effectively decouples the expected grain size/eU age correlations.

Using the equivalent spherical radius approximation for modeling individual grain ages implicitly assumes that analyses are carried out on whole grains. A logical conclusion would be to pick and analyze only whole grains. However, we show here that the pattern of dispersion of fragment ages mirrors the shape of the He diffusion profile and thus contains information on the thermal history, and so rather than avoiding broken grains we suggest they should be specifically targeted. We also demonstrate that picking grains without any terminations (0T grains) will likely yield reproducible ages, but will almost certainly over-estimate the true whole grain age. Picking grains with single terminations (1T grains), with a wide range of widths and fragment lengths, is probably the best practice as these can be relatively easily modeled. Also, 'short' fragments that are wider than they are long contain valuable information and should be systematically included in the analyses where possible.

We conclude that grain selection and picking should focus on maximizing the natural dispersion, not minimizing it. We recommend that best practice should aim to pick and analyze more fragments. To properly document and characterize the pattern of age dispersion likely requires circa 20-30 single crystal ages per sample, and so would recommend that cost effective strategy might be to analyse more grains from fewer samples and that the thermal history constraints be obtained by modeling the age dispersion explicitly while treating broken grains as fragments of larger grains as appropriate. The alternative, of analyzing circa 3 grains from many samples, often produces ambiguous data with limited thermal history information.