

Geochronological pitfalls in petrochronological research – the case of instrumental elemental fractionation effects

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Petrochronological investigations have developed into a back-bone of hard-rock geology by routinely combining geochronology (mostly age data from in-situ U-Th-Pb dating) and petrology thus allowing to gain deeper insights into the P-T-t evolution of metamorphic and magmatic rocks.

An underlying assumption is that both the geochronological and the petrological data used to establish the P-T-t models are both accurate and precise. But the in-situ dating community has for a long time known that instrumental elemental fractionation effects (IEF), often called „matrix effects“, can be detrimental to the achievable overall accuracy, and to some extent also the precision of in-situ ages. Uncorrected IEF can cause age shifts of several %, as has been shown for zircon, monazite, xenotime, rutile.

IEF have three different sources: a) variable crystal chemical composition; b) crystallographic orientation of the analysed mineral; c) experimental setup.

Ad a) Corrections schemes have been proposed which claim that the procedures successfully correct for IEF. Corrections schemes are mostly one-dimensional. For example are Th or U concentrations of monazite used to correct the IEF of SIMS dating; Y and REEs concentrations can be used to correct the IEF of xenotime SIMS and LA analyses. But it has been demonstrated that these one-dimensional corrections are not sufficient to effectively correct IEF. Multi-dimensional corrections schemes are recommended to allow for properly correcting the IEF for any given mineral composition. Such multi-dimensional IEF effects are widespread. This means, that age data gained on minerals showing a large variability in composition are prone to exhibit IEF and thus are not properly corrected for by using published one-dimensional IEF correction schemes. But it is exactly the correlation of changing mineral composition with changes in P-T conditions which is used for petrochronological investigations. This means that the observed correlation of mineral ages and P-T conditions can be spurious and so geologically misleading. Observed age differences can at least in parts be analytical (from IEF) and do not necessarily reflect i.e. protracted mineral growth on a certain part of a P-T evolution. It is thus proposed that petrochronological age data be thoroughly tested for IEF and that multi-dimensional corrections scheme are i) established and ii) routinely used.

Ad b) Crystallographic orientation has shown to be of importance for SIMS analysis of baddeleyite and cassiterite leading to age deviations of several percent. Published data seems to indicate that no analytically resolvable orientation effects are present for zircon and monazite. For LA analysis no orientation effects have been reported yet. For petrochronological data to become geologically more significant orientation effects have to be investigated systematically. This is especially true for in-situ analyses in thin sections or polished rock slabs. Mineral grains embedded in epoxy resin disks show a non random crystallographic orientation (i.e. zircons are embedded parallel the c-axis) thus minimizing orientation effects of IEF. In contrast to this minerals in situ show a \pm random orientation thus making orientation effects on IEF more critical.

Ad c) The influence of different instrumental setups on IEF can nowadays be properly corrected for. It is thus proposed that these IEF are of minor importance when compared to the other two sources of IEF.