Geophysical Research Abstracts
Vol. 12, EGU2010-3220, 2010
EGU General Assembly 2010

Advances and limitations on interpreting the erosional record from isotopic analysis of single detrital mineral grains

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The analysis of provenance of clastic sediments is useful for reconstructing the characteristics and rates of exhumation of source areas, and sometimes placing minimum age constraints on depositional age. Due largely to increased availability and ease of access to LA-ICP-MS instrumentation, the analysis of provenance using single detrital accessory minerals has grown very rapidly over recent years. With this however is a culture of casual users who may not fully appreciate subtleties of measurement and isotope interpretation. The isotopic provenance literature is dominated by zircon-centric studies that use U-Pb dating and Hf isotope measurements of single zircons, but unfortunately an increasing number of these studies appear to lack sufficient understanding of U-Pb and Hf systematics; misleading interpretations are increasingly common. The inherent information contained in detrital accessory minerals is potentially immense, scientifically, but comprehensive interpretations attempting to reconstruct the geological make-up and evolution of sources require dating of multiple types of accessory minerals (i.e. zircon, titanite, monazite, garnet inclusions, micas, allanite, rutile, apatite) by various methods (U-Pb, fission track, Ar-Ar…) at times accompanied by isotope geochemical data (Lu-Hf, Sm-Nd, Rb-Sr) of phases where Sr, Hf, or REE comprise a major element ($\geq$0.5%). Many approaches have been demonstrated but the mix of methodologies needs to be tailored to the problem, in view of the variable effort and expense needed to acquire good datasets. To date there are few comprehensive multi-mineral, multi-isotope system applications, and too many studies that follow a prescriptive cookbook that lacks innovation and fails to address a problem. The field needs to focus effort on the approaches that can solve a problem well rather than doing either just the easy methods or too many methods only moderately well. Zircon studies require strategies that reduce or eliminate discordance, collect sufficient data on each grain to make a robust age interpretation, improve accuracy of data by more attention to standards and uncertainties, can analyze thin overgrowths that reveal the magmatic or metamorphic age, and minimize sample consumption, not an easy task for the vast majority of laboratories doing provenance applications. Detrital monazite, monazite-in garnet, titanite and rutile can reveal much of the higher temperature metamorphic time-temperature path, and coupled U-Pb and fission track studies of single zircon and apatite grains can be useful for determining lower temperature exhumation rates. Isotope geochemistry (Hf-Nd-Sr-O) is more time consuming but can be pivotal to distinguish subtle differences in sources and to test specific hypotheses. Examples of improved methods and applications will be presented to illustrate the presentation.