Geophysical Research Abstracts
Vol. 20, EGU2018-3675, 2018
EGU General Assembly 2018

Bias in sedimentary provenance studies

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Bias is inevitable and occurs in every step of sedimentary provenance analysis. Fortunately, many sources of bias are well understood and can be minimised or corrected for:

1. Sample collection: selective entrainment of less dense grains creates placers and antiplacers, which makes sample collection a non-trivial exercise. Fortunately, the mathematical behaviour of hydraulic sorting is well understood and it is generally possible to undo its effects and restore the mineralogical composition to some assumed grain density.

2. Mineral separation: destroys all textural information within a rock sample, increases the chance for sample cross-contamination and may introduce bias. For example, magnetic separation may preferentially remove old and metamict zircons, as well as small zircon inclusions in other minerals such as biotite or garnet, which may contain key petrological information. These biases can be largely removed by tasking an Automated Phase Mapping (APM) system by SEM or Raman analysis to find the zircons, thereby avoiding most steps in the mineral separation process.

3. Point counting: traditional sedimentary petrography determines the mineralogical composition of sand(stone) by observing the composition of a representative number (i.e. hundreds) of randomly selected points in a grain mount using the 'Indiana' or 'Gazzi-Dickinson' methods. New approaches use SEM-based APM to determine the area percentages of the different minerals. These analytical protocols may yield contrasting results depending on the composition and grain-size distribution.

4. Grain size: the settling equivalence between small grains of dense minerals and larger grains of less dense minerals causes a strong intrasample correlation between grain size and mineralogy, which can strongly bias the results of heavy mineral studies if a narrow size window is used rather than the bulk sample.

5. Hand picking: detrital geochronology by SIMS or LA-ICP-MS presents the analyst with a number of practical decisions, such as which grains to date and where to place the ion- or laser beam. One approach is to hand-pick zircon grains and subject them to cathodoluminescence imaging prior to U-Pb analysis, in order to identify and target cores or rims. A second school of thought is that the less is known about the sample prior to U-Pb analysis, the better. This approach avoids hand picking and CL-imaging so as to minimise any selection bias.

6. Choice of provenance proxies: a plethora of chemical, mineralogical and isotopic properties can be used to constrain sedimentary provenance. Each of these has its strengths and weaknesses. Multi-mineral proxies such as bulk-sediment petrography provide a rich source of compositional information that can provide valuable information about the lithology of sediment sources. Major-element geochemistry provides clues to evaluate climate-related pre-depositional weathering, whereas trace-element geochemistry is the best way to detect hydraulic sorting effects. In contrast, single-mineral proxies such as zircon U-Pb geochronology are largely immune to hydraulic sorting, but they carry little petrological information and their resolving power is reduced by sediment recycling. The best way to overcome these limitations is to combine several methods. Statistical treatment is required to make geological sense of the resulting 'big' datasets.