Sediment source characterization by non-negative matrix factorization of detrital zircon U-Pb data and application to Upper Cretaceous strata of the Book Cliffs, Utah

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Detrital geochronology has become among the most widely used tools to determine source-to-sink pathways. Its applications range from reconstructing tectonic processes and the relative position of tectonic plates and terranes in deep time, to identifying changes in sediment routing and delivery in the Anthropocene. The geographic connectivity implied by through-flowing rivers can also inform models of biological evolution and faunal dispersion. However, whereas technical advances have expedited characterization of basin samples, identifying potential sources remains a challenge: particularly if those sources have been removed by erosion or tectonic processes.

We present an inverse approach to the problem of characterizing sediment sources' ("source" samples) age distributions based on samples from a particular depocenter ("sink" samples) using non-negative matrix factorization (NMF). We also present a method to determine the optimal number of sources to factorize from a set of sink samples (i.e., the optimum factorization rank). We demonstrate the power of this method by generating sink samples as random mixtures of known sources, factorizing them, and recovering the number of known sources, their age distributions, and the weighting functions used to generate the sink samples.

In order to validate the algorithm in a geological setting we apply it to an empirical example found in the Upper Cretaceous strata of the Book Cliffs, Utah. Factorization of the Book Cliffs data set yields five sources very similar to those recently independently proposed as the primary sources for Book Cliffs strata: confirming the utility of the NMF approach. Application of the NMF approach indicates that Book Cliffs strata are comprised of a mixture of northern, western, and southern sources, with a relative increase and then decrease in the northern source through time.