Deciphering sedimentary recycling via multiproxy *in situ* analyses.

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Sedimentary rocks and modern sediments sample large volumes of the Earth's crust, and preserve units that vary greatly in age and composition. Determining the provenance of component minerals is complicated by the ability of some minerals to be recycled through multiple sedimentary cycles. To untangle these multi-stage signals, two or more chemical signatures measured in minerals with different stability are required, such as Pb in K-feldspar and U–Pb/Hf in zircon.

One sedimentary succession suitable for testing this hypothesis is the Upper Carboniferous Millstone Grit Group, a fluvio-deltaic, upward-coarsening sequence of mudstones, sandstones and conglomerates deposited in the Pennine Basin of northern England. New K-feldspar data clearly indicate two dominant populations with $^{207}Pb/^{204}Pb$ ratios of *c*. 13.5 and 18.5, consistent with Archaean–Palaeoproterozoic and Caledonian material, respectively. Zircon U–Pb data from the same rocks record two peaks at *c*. 400 and 2700 Ma, most likely corresponding to the two K-feldspar peaks, while a broad spread of U–Pb ages between 900-2000 Ma have no direct corollary and are most likely recycled. Zircon Hf model ages form two broad peaks at *c*. 2000 and 3300 Ma, indicating the Caledonian granites are derived from reworked older crust and their common Pb ratios were reset during crystallisation.

These distributions are consistent with a stable source area stretching from Labrador to Scandinavia, including younger material from Scottish Caledonian granites or their offshore correlatives. Hf model ages are the least useful for fingerprinting unique source rocks, but can discriminate between single and multiple sources for each U–Pb population. Changing proportions of both K-feldspar and zircon distributions within the Group may correspond to changes in environmental or storage conditions within the feeder river system. Further work is needed to quantify the processes controlling these fluctuations, and the possible biasing of effect of grain size on zircon age distributions.