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Alternatives to zircon: Case studies in foreland basin detrital provenance analysis employing under-utilised proxies

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Foreland basin sediments are key archives of orogenic development, preserving a record of past tectonic and climatic processes. This record can be read by employing single-grain detrital geo- and thermochronometers as detrital provenance indicators. Detrital provenance plays a crucial role in Earth Science as a research multiplier: c. 3,800 published articles with these keywords have been cited c. 92,000 times (c. 59,000 times in the last five years; Clarivate Analytics Web of Science), the bulk of which (c. 2,800/3,800) employed detrital geo- or thermochronometry. Fundamental to this approach is the assumption that tectonically- or climatically-driven changes in the location or tempo of erosion will expose thermochronologically distinctive sediment sources within the orogen. The chosen mineral thermochronometer(s) must therefore possess three key characteristics: (1) an appropriate thermal and chemical sensitivity, which will yield reset ages in a limited but non-zero number of source units; (2) occur in a wide range of source rock types, to prevent lithological bias; and (3) be sufficiently mechanically and chemically stable at the Earth's surface to allow widespread preservation in sedimentary rocks.

However, a large majority of published detrital provenance studies utilising geo- or thermochronometry (c. 2,200/2,800) employ the zircon U-Pb technique. This phase is highly favourable analytically, incorporating high U and Th concentrations and often trivial common-Pb. However, zircon is often subject to bias, especially with regard to source lithology, and thermal and chemical sensitivity. In orogens which lack widespread felsic magmatism the zircon U-Pb age distribution is typically dominated by ages recording older geological events, inherited by recycling through sedimentary and metamorphic rocks incorporated in the orogenic wedge.

In many cases, therefore, the use of multiple thermochronometers, present in a wider range of source lithologies and exhibiting a more varied thermal and chemical sensitivity is required. Here, we present case studies from the Alpine, Himalayan, and Caledonian orogens, exploring the possibilities and limitations of detrital U-Pb and elemental abundance analysis of apatite, rutile, and titanite, which we contrast with zircon U-Pb data.