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Exhumation history of the New Zealand Southern Alps from detrital thermochronology of the Waiho-1 borehole

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The Southern Alps of New Zealand is a model orogen for studying the influence of focused erosion on the evolution of convergent plate boundaries. Since the early Miocene, convergence between the Pacific and Australian plates has progressively exhumed crust of the Pacific Plate in the hanging wall of the Alpine Fault, an oblique strike-slip fault that delimits the western margin of Southern Alps topography. Terrigenous sediment deposited in basins west of the Alpine Fault has preserved a detailed record of early mountain exhumation in Miocene sedimentary sequences. This study reconstructs a detailed history of early Southern Alps exhumation by interpreting the cooling of detrital minerals in this western sedimentary record.

The long-term (>10˘6 yr) exhumation history of this plate boundary has been previously interpreted from thermo-kinematic modeling of bedrock thermochronology densely sampled across the orogen. Bedrock thermochronology constrains a Late Miocene onset of Southern Alps exhumation associated with the ongoing Kaikoura orogeny, decreasing from 8 Ma to 5 Ma northwards along strike of the Alpine Fault. These prior analyses provide an initial hypothesis to test with new detrital analyses of Miocene sedimentary units deposited west of the Alpine Fault.

To test this hypothesis, we present new detrital zircon fission-track thermochronology from twenty samples of the Waiho-1 borehole, a 3.6 km continuous sedimentary sequence. Biostratigraphy indicates that the base of the borehole reaches at least the Middle Miocene >14 Ma. Published provenance analyses of metagreywacke clasts in conglomeratic horizons indicate that sediment sources have changed during deposition of the sequence, with material derived from terranes east of the Alpine Fault observed since 7.5 Ma. High-grade schist from the orogenic root of the Southern Alps first appears in the sequence at 4 Ma.

Using biostratigraphic control of sample depositional ages, we calculate lag-time components from detrital zircon fission-track cooling age populations. We observe three primary lag-time components from the composite dataset. Lag-time components >150 Myr represent original depositional ages unreset by subsequent exhumation. Lag-time components ~60-100 Myr represent a period of cooling associated with late Cretaceous crustal extension of the Pacific Plate, and may be partially reset by more recent exhumation. Lag-time components ~20 Myr reflect cooling associated with inception of the Alpine Fault and onset of the Kaikoura orogeny. This youngest lag-time component decreases up section after 7 Ma with a clear trend observed in samples after 4 Ma.

An up-section decrease in lag-time during the Late Miocene-Pliocene indicates increasing exhumation rates in the early Southern Alps source area and is broadly consistent with thermo-kinematic modeling of bedrock analyses. For comparison, we predict lag-time assuming several proposed model scenarios. Lag-time predictions illustrate where our detrital models diverge from interpretations based on bedrock analyses. Ongoing complimentary detrital apatite fission-track thermochronology, Raman spectroscopy of carbonaceous material, and clast provenance analyses of contiguous units will further provide independent constraints on the onset timing, and along-strike variability in early Kaikoura exhumation - new data for future modeling of both source rock exhumation and basin burial histories.