U-Pb and trace element depth-profiling of Alpine Schist zircon: constraining tectonic processes during the late stages of Gondwana breakup

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Recent studies in ‘geospeedometry’ indicate that time scales of regional metamorphism can be extremely variable, with estimates for different regions ranging from as long as >50 Ma to as short as 10 ka – 1 Ma (Viete et al. 2010). As metamorphic mineral growth results from transient processes such as solid-state metamorphic reactions, fluid infiltration, or melting reactions, a single mineral is capable of recording a complex distribution of ages and chemistries, yet may only record a short snapshot of a much longer metamorphic event. However, by sourcing information from multiple minerals in the same rock, we can piece together the larger regional metamorphic history in order to decipher the timing and duration of tectonic processes responsible for metamorphism.

The Alpine Schist of New Zealand is an example of a metamorphic terrane that has experienced a complex history of prolonged metamorphism since the late Cretaceous. Accretion and metamorphism of the greywacke Alpine Schist protolith occurred during the Mesozoic at the long-lived Paleo Pacific-Gondwana subduction margin. After subduction at the Pacific-Gondwana margin ceased at ~90 Ma, Zealandia underwent stretching and thinning, as evidenced by metamorphic core complexes and conglomerates infilling rift valley basins, culminating in rifting and sea-floor spreading from ~85 Ma. The Alpine Schist represents the last addition of continental crust to the Zealandia portion of the Pacific-Gondwana margin, and therefore records the tectonic processes occurring during the final stages in the breakup of Gondwana. My work focuses on dating the Alpine Schist metamorphism in order to investigate the timescales and spatial distribution of Gondwana breakup.

Garnet Lu-Hf geochronology indicates that prograde metamorphism occurred in the Alpine Schist from at least 93 Ma to 75 Ma, during a period of lithospheric thinning, extension, rifting and sea-floor spreading. Although garnet is one of the most reliable minerals for dating prograde metamorphism, the whole-grain dissolution method used in Lu-Hf garnet geochronology provides

![Figure 1: Concordia plot showing data from individual laser pulses from one spot analysis, colored by depth. Shallow pulses contain common Pb, making data points discordant above Concordia. Data from intermediate depths show mixing between young rims and old cores.](image-url)
only a ‘mean age’ for the time period over which garnet growth actually occurred. Unlike garnet, zircon often crystallizes later in the metamorphic cycle as a result of melting reactions or fluid infiltration, and may experience multiple episodes of growth within one metamorphic cycle. However, this information is typically preserved in fine metamorphic zircon overgrowths that are too thin to analyze using conventional laser ablation methods.

This summer, we used the newly developed laser ablation split-stream inductively coupled mass spectrometry (LASS-ICP-MS) depth-profiling method to perform U-Pb and trace element analyses on the surfaces of Alpine Schist zircon crystals. As opposed to the analysis of sectioned zircons, surface analysis ablates from the surface of the zircon crystal inwards, providing depth-profiles through thin 5-10 µm metamorphic zircon overgrowths at ~100 nm depth resolution (Fig. 1).

The 14 samples analyzed this summer consist of Pre-Cambrian to Mesozoic detrital zircon cores with significantly younger overgrowths, ranging from ~100 Ma to as young as 5 Ma. The overgrowths have distinctively low Th/U ratios (<0.5) compared to cores (≥0.5), consistent with metamorphic zircon crystallization (Fig. 2C). In the southernmost Alpine Schist samples, depth-profiles indicate that zircon crystallization was continuous from ~80 – 40 Ma. This time period overlaps with the age range of anatectic melts in the Alpine Schist, suggesting that zircon growth is related to partial melting and/or fluid flux in this area. Elsewhere in the Southern Alps where anatectic melts are absent, young zircon overgrowths could result from fluid influx sourced from deeper structural levels. Further interpretation of the trace element data collected during the depth-profile analyses will clarify whether zircon crystallization occurred simultaneously with garnet growth.

Our initial results demonstrate that depth-profiling of zircon is capable of revealing continuous and prolonged crystallization histories from thin (<5 µm) zones that are not possible to resolve using conventional techniques.

![Figure 2: B) Age depth-profile; C) Th/U depth-profile for a single zircon crystal](image)
References: