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Linking zircon age to metamorphic stage using U-Pb/REE depth-profiling of zircon combined with Lu-Hf garnet geochronology

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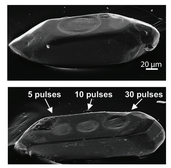
Motivation

Zircon is capable of (re)crystallizing at any stage during metamorphism. Recrystallization events are often preserved in thin (<10 um) rims on inherited zircon grains in metamorphic rocks. Laser ablation split-stream (LASS) depth-profiling of unpolished zircon surfaces has enabled U-Pb isotope and trace element analysis of these thin zircon domains.

The potential value of this high spatial resolution method as a petrochronologic tool hinges on the question:

Can zircon depth-profile data be linked to specific metamorphic conditions and tectonothermal events?

We address this question by applying the depth-profiling method to zircon from amphibolite facies Alpine Schist (New Zealand) dated previously by Lu-Hf garnet geochronology and assessing:
1) rare earth element (REE) partitioning between zircon and garnet
2) independent constraints on the timing of garnet growth, and generation of anatectic pegmatites.

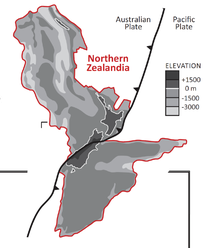


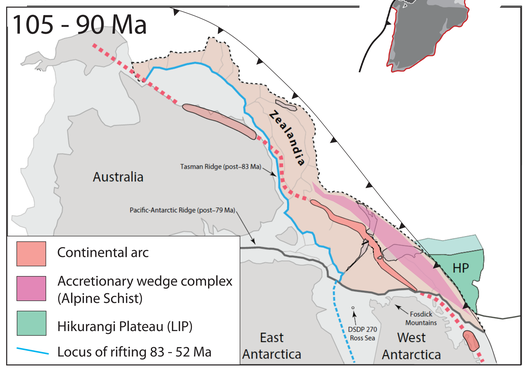
Cottle et al. 2009

Geologic setting

The newly proposed geologic continent Zealandia is 94% submerged below sea level. Uplift along the active Pacific-Australia plate boundary exposes the Alpine Schist accretionary wedge complex in the South Island.

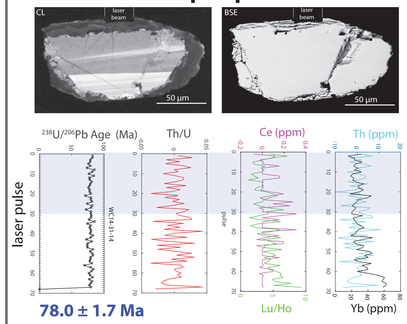
Zealandia was assembled at the paleo Pacific-Gondwana margin during Mesozoic subduction. The Alpine Schist represents the metamorphosed sediments of the accretionary wedge complex, long thought to have been metamorphosed during Jurassic – Cretaceous subduction. New metamorphic dates show that the Alpine Schist records metamorphism occurring concurrently with rifting and the final stages of break-up of Gondwana.



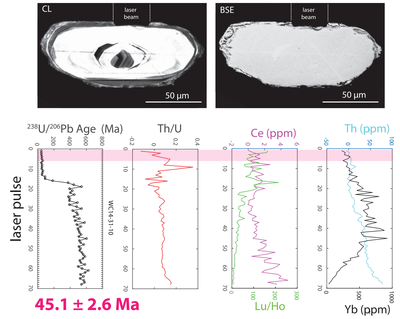


Results

LASS zircon depth-profiles:



Depth profile samples thick, chemically homogeneous rim. Convolute zoning and inclusions/porosity at core-rim interface indicate earlier modification by a dissolution-reprecipitation process.

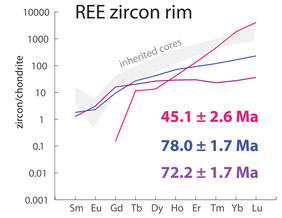


Depth profile samples thin convolute rim followed by an older, dark un-zoned domain. Porous texture of convolute rim indicates modification by dissolution-reprecipitation.

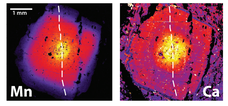
D_{REE} Summary:

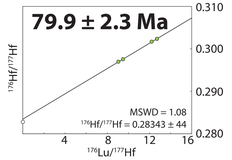
An amphibolite facies schist (WC14-31) yields 3 distinct zircon rim ages, two of which are close in age to garnet from the same sample.

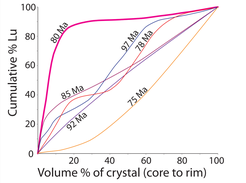
Calculated zircon/garnet REE partition coefficients overlap with published values for zircon that formed during garnet-stable conditions.



Lu-Hf garnet geochronology:





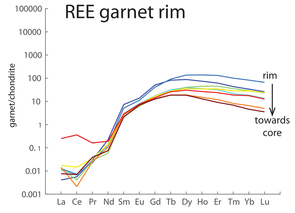


EPMA garnet compositional maps.

Lu distribution of WC14-31 garnet (bold) indicates age may be biased toward core.

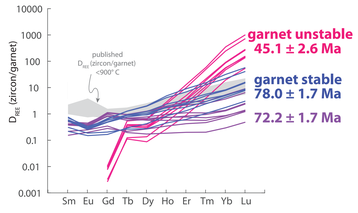
Lu-Hf isochron comprising four multi-grain garnet aliquots provides the 'mean age' of garnet growth.

Garnet chemistry:



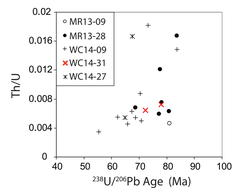
Garnet rim REE abundance (LA-ICP-MS). Profiles colored by distance of the analysis from the garnet rim.

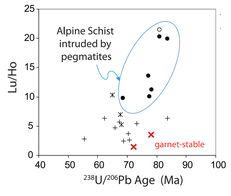
D_{REE} (zircon/garnet):



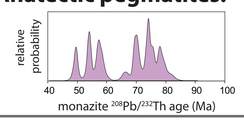
REE partition coefficients (REEppm zircon/REEppm garnet) using zircon rim average coupled with 8 garnet rim analyses.

Zircon rims summary:



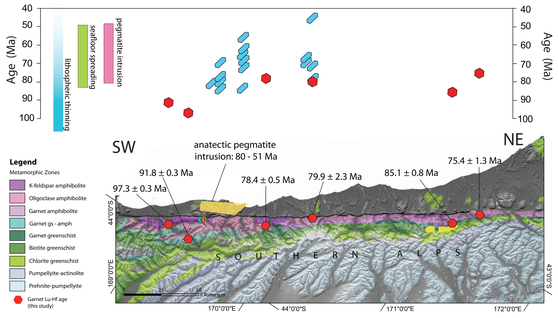


Anatectic pegmatites:



Alpine Schist intruded by **anatectic pegmatites** yields zircon rims with higher sumREE and enriched HREE (high Lu/Ho ratio).

These zircon rims likely formed either during **fluid/melt influx** associated with pegmatite intrusion, or during **garnet-unstable conditions.**



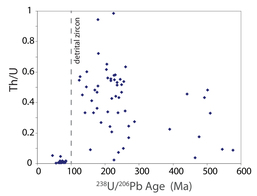
Alpine Schist garnet and zircon (re)crystallization is contemporaneous with the rifting of Zealandia from Gondwana during 83 – 52 Ma.

Method

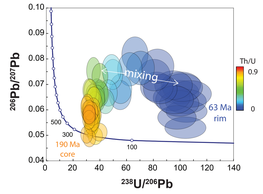
Zircon was mounted on flat crystal faces in epoxy. Unpolished surfaces were analysed by LASS-ICP-MS using **35 µm spots for 40 seconds at 2 Hz = 80 shots.**

Data selection criteria:

1) ≥10 data point 'plateau' age
2) no mixing or incomplete re-equilibration
3) Th/U correlates with age
4) REE is reset, not inherited from core



Metamorphic zircon overgrowths are easily distinguished from igneous cores based on Th/U (<<1)



Concordia plots show mixing between modified zircon rims and unmodified, inherited igneous cores

Implications

Depth-profiling is capable of resolving multiple zircon growth/modification events spanning a significant portion of a rock's metamorphic history.

Zircon rims formed during garnet-stable conditions are distinctly depleted in HREE, and yield D(REE) zircon/garnet values consistent with published values.

Zircon rims formed during fluid/melt influx are characterized by enriched HREE and convoluted internal zoning.

Limitations: the presence/absence, thickness and continuity of zircon rim domains is not predictable and may be governed by location of zircon in the rock and/or access to fluids/melts.

Regional implications: Both garnet and zircon (re)crystallization in the Alpine Schist are contemporaneous with the rifting of the Zealandia microcontinent from East Gondwana during 83 – 52 Ma, suggesting that compressional and extensional tectonic regimes existed in close proximity during the formation of the Zealandia microcontinent.

References

Rubatto, D., & Hermann, J. (2007). Experimental zircon/melt and zircon/garnet trace element partitioning and implications for the geochronology of crustal rocks. Chemical Geology, 241(1), 38-61.
Hermann, J., & Rubatto, D. (2003). Relating zircon and monazite domains to garnet growth zones: age and duration of granulite facies metamorphism in the Val Malenco lower crust. Journal of Metamorphic Geology, 21(9), 833-852.
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