Rare Earth Element Guided Zircon Geochronology

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Introduction

The development and advances in high precision dating techniques, such as high resolution ion microprobe (SHRIMP, Cameca 1270), has enabled us to identify and differentiate mutliple phases of zircon growth that may be separated in time by hundreds of millions of years. However, the relative timing of metamorphic zircon growth during a metamorphic event, or between individual metamorphic events is still commonly ambiguous. As a first step to differentiating separate phases of zircon growth and/or modification within a single sample, and then linking these phases of growth to individual metamorphic events, detailed cathodoluminescence (CL) and backscattered electron (BSE) imaging may be used. Such detailed image analysis combined with microbeam REE analysis of individual domains within zoned zircon grains can place zircon ages within improved textural and chemical context, and so enable more rigorous interpretation.

Aims of project

The samples studied form part of a suite from the Napier Complex, east Antarctica, originally dated by Harley & Black (1997) unguided by CL/BSE imaging. The original interpretation of these age data reflects this lack of key textural information. The aim of the current study was to carry out:

1) detailed SEM (CL & BSE) image analysis of the zircon grains;

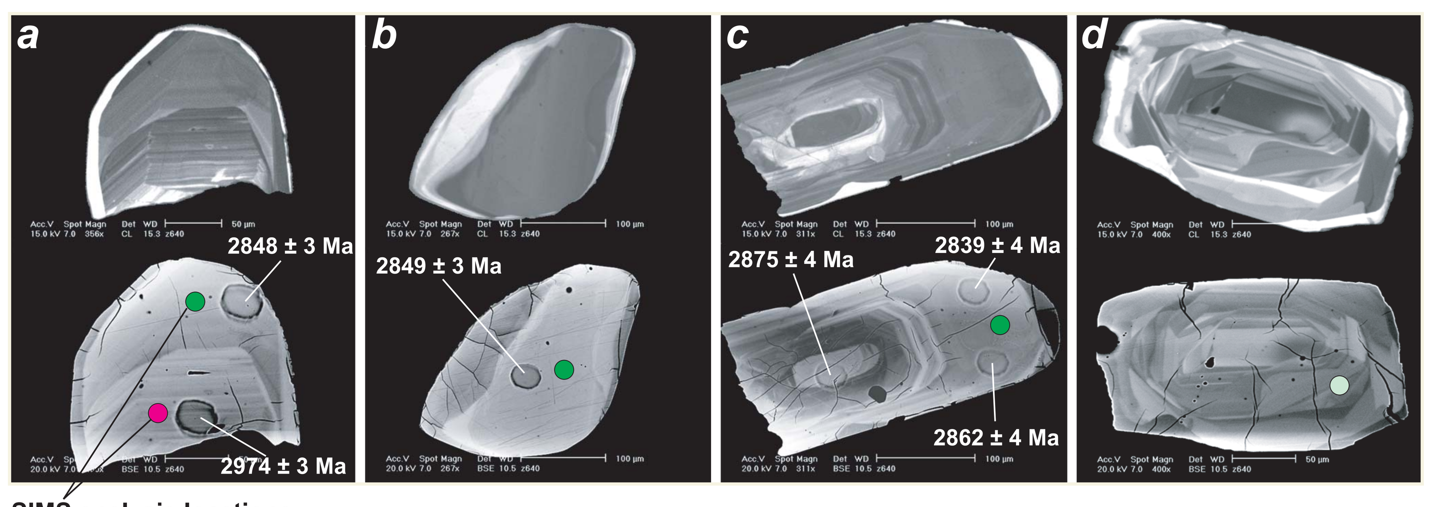
2) rare earth element (REE) analysis of zircon grains and associated garnet and/or orthopyroxene present in samples to differentiate internal zones in the zircon grains and where possible place in an assemblage context;

3) re-interpret original SHRIMP data in light of image and chemical analysis.

SEM

Garnet-absent Charnockite

Perthite, quartz, plagioclase, orthopyroxene and hornblende-bearing igneous charnockite, that, based on field observations, is interpreted to have intruded during the earliest event recognised in the Napier Complex: D1/M1.



SIMS analysis locations

Figure 1: CL (top row) and BSE (bottom row) images of zircon grains from the garnet-absent charnockite. (a) zircon fragment with magmatic core, moderate CL broad banded overgrowth and narrow high CL rim; (b) low CL metamorphic core with high CL rim; (c) xenocrystic inner core within oscillatory zoned outer core, with moderate CL overgrowth and narrow high CL rim; (d) Moderate to high CL metamorphic zircon grain with sector and banded growth zoning.

REE

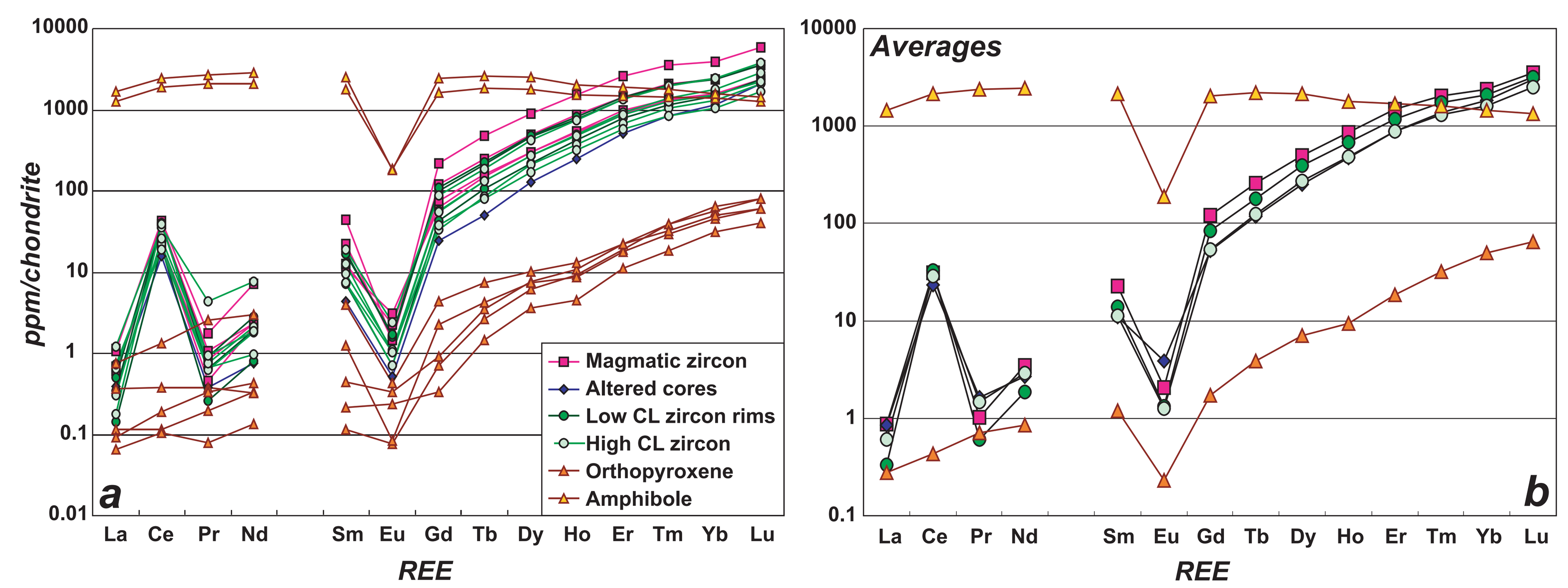
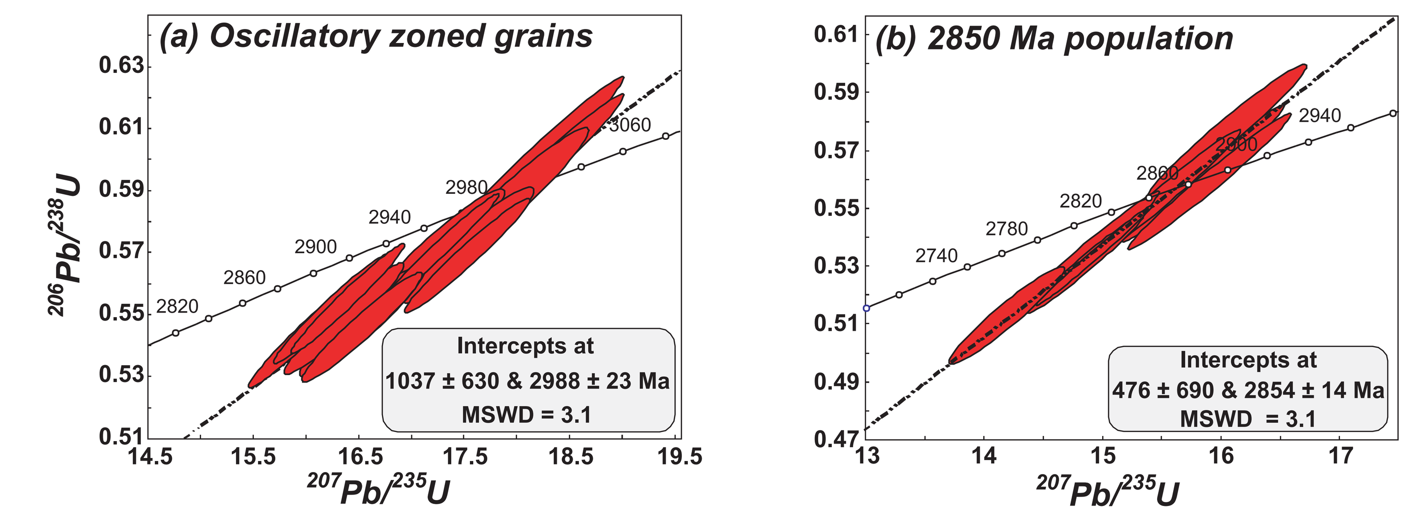


Figure 2: Chondrite-normalised REE data for zircon, orthopyroxene and amphibole from garnet-absent charnocite: (a) all analyses; (b) average data.

* *Magmatic zircon* (**Fig. 1a,b**): steep REE patterns typical of magmatic zircon (**Fig. 2**)
* *Low CL, mantles and rims* (**Fig. 1a,b**): slightly depleted in MREE rel. to magmatic zircon
* *High CL rims* (**Fig. 1a-d**): larger depletions in MREE and minor depletions in HREE
* *Altered zircon cores:* similar REE patterns to high CL rims
* *Orthopyroxene:* M-HREE's low in concentration but patterns mimics that of zircon

U-Th-Pb data



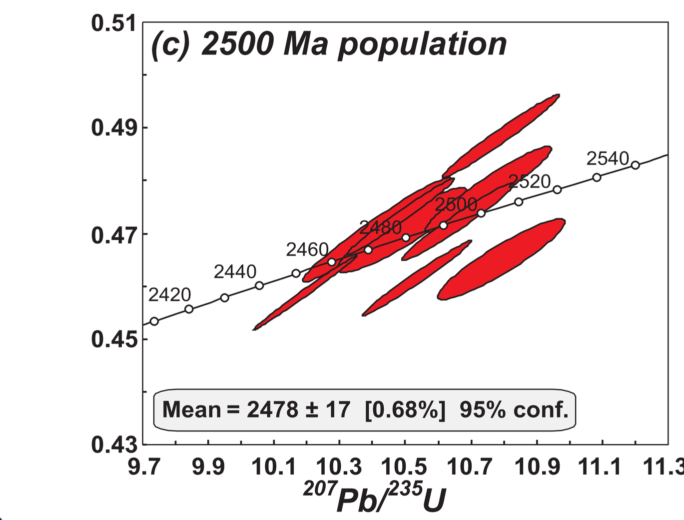


Figure 3: U-Th-Pb SHRIMP data:
(a) Oscillatory zoned grains: upper intercept age reflects the age of crystallisation;
(b) Data from recrystallised magmatic grains, low CL outer cores/rims indicates the age of early metamorphism in the Napier Complex;
(c) Moderate-high CL grains and rims: average $^{207}Pb/^{206}Pb$ age indicates the timing of a second phase of metamorphism, interpreted to be a regional ultra-high temperature event.

Garnet-bearing Orthogneiss

Originally interpreted to be syn-deformational and intruded during a D1/M1 event at ~2850 Ma. Preserves an intense "S1" gneissosity defined by quartz, mesoperthite, orthopyroxene and minor garnet, that formed during UHT metamorphism (*T*=1050-1120°C, *P*=7-11 kbars).

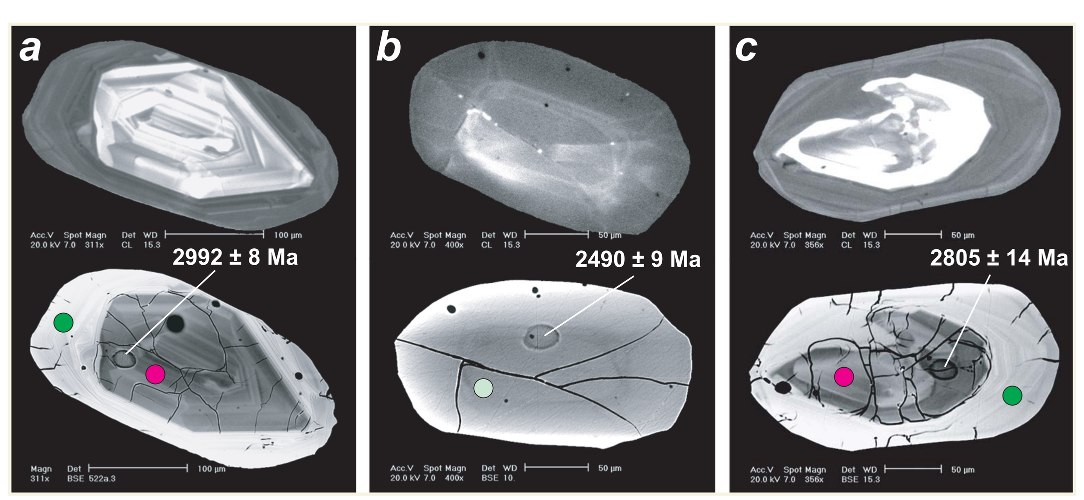


Figure 4: CL (top row) and BSE (bottom row) images of zircon grains from the garnet-bearing orthogneiss. **(a)** magmatic core with banded, moderate-low CL overgrowth; **(b)** moderate CL grain with planar banding and sector zoning; **(c)** magmatic core, with an altered margin separating it from a banded, moderate CL

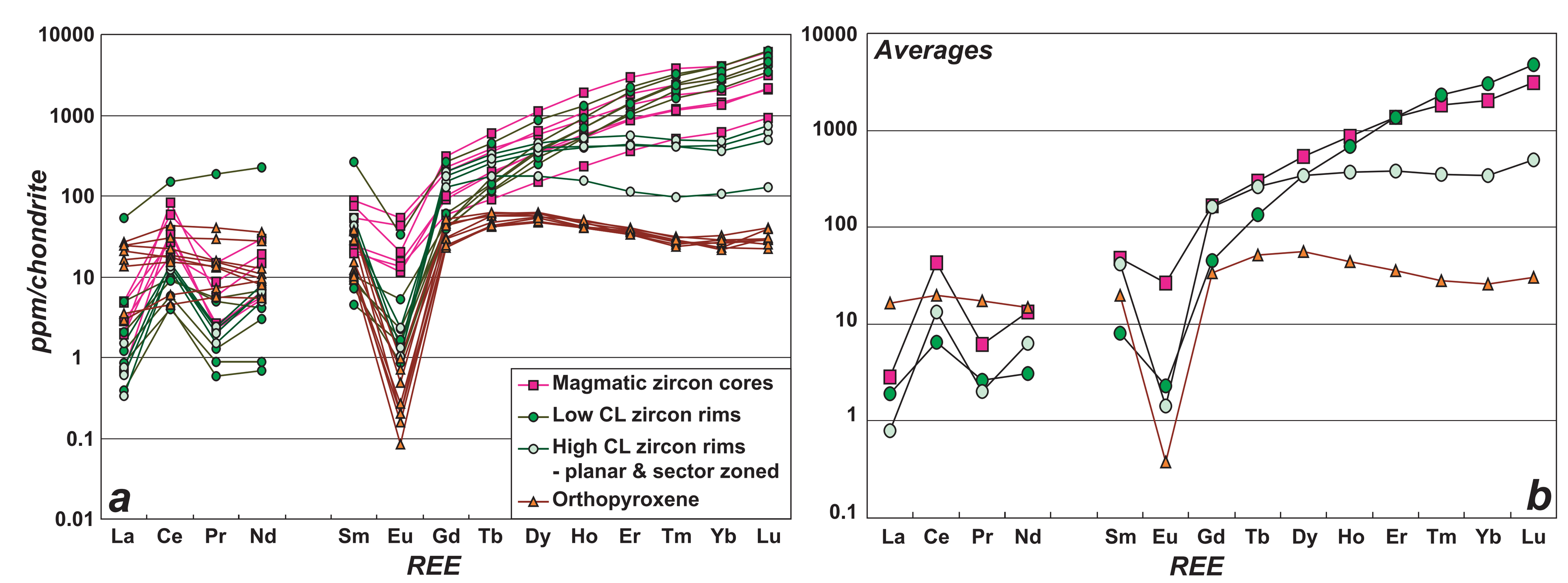
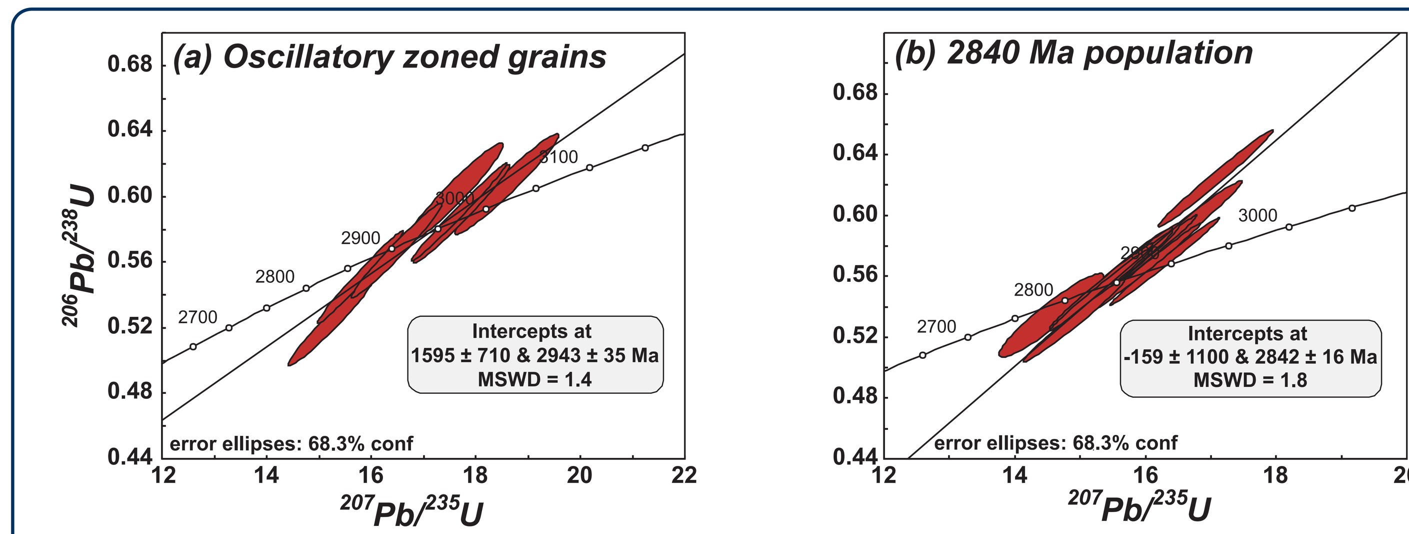


Figure 5: Chondrite-normalised REE data for zircon and orthopyroxene from garnet-bearing orthogneiss: (a) all analyses; (b) average data.

* *Magmatic zircon* (**Fig. 4a,c**): steep REE patterns typical of magmatic zircon (**Fig. 5**)
* *Low CL rims, with weak planar banding* (**Fig. 4a,c**): depleted in MREE and enriched in HREE relative to the magmatic zircon
* *High- to moderate CL rims, moderate CL grains (planar growth banding and sector zoning;* **Fig. 4b**): significantly depleted in HREE, "flat" REE patterns similar to orthopyroxene; both resemble typical garnet patterns



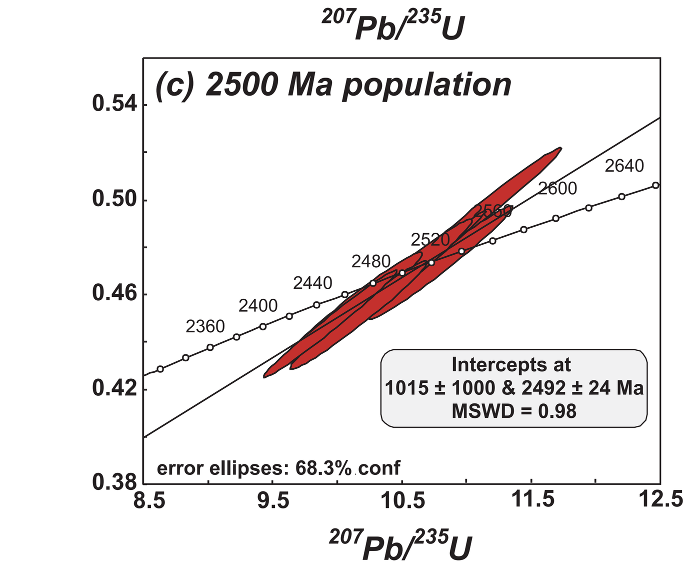


Figure 6: U-Th-Pb SHRIMP data:
(a) Oscillatory zoned grains: upper intercept age reflects the age of crystallisation;
(b) Data from low CL outer cores/rims & recrystallised magmatic grains, indicates the age of early metamorphism in the Napier Complex;
(c) Moderate CL grains and rims: average upper intercept age indicates the minimum age of the garnet-orthopyroxene gneissosity.

Conclusions

* Different generations of zircon growth have distinct REE concentrations and patterns
  eg. metamorphic zircon grew in garnet-bearing orthogneiss at *c.*2850 Ma in the absence of garnet, possibly at lower PT's than metamorphic zircon that grew at *c.*2500 Ma in the presence of garnet.
* the REE chemistry of zircon and associated minerals can be used to link stages of zircon growth with a specific foliation

Future Directions:

* Application of similar imaging and REE criteria to zircons from rocks of other complex, high-grade terrains with controversial chronologies, to resolve P-T-*t* histories: e.g. South Harris, Outer Hebrides, NW Scotland.
* Use of the Cameca 1270 facility to carry out U-Pb dating of REE charactersied zircons.

Acknowledgements

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