Lithium in >4.0 Ga Jack Hills zircons

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Abstract

In situ Li analyses of 4348 to 3350 Ma detrital zircons from the Jack Hills, Western Australia by SIMS reveal that the Li abundances (typically 10 to 65 ppm) are commonly over 10,000 times higher than in zircons crystallized from mantle-derived magmas and in mantle-derived zircon megacrysts (typically <2 ppb). The Jack Hills zircons also have fractionated Li isotope ratios (FLI = 19 to +33 %) about five times more variable than those recorded in primitive ocean floor basalts (2 to 8 %), but similar to continental crust and its weathering products.

Why lithium?

(1) Li is moderately incompatible Li would be concentrated in zircons from the evolved magma.
(2) Li isotopic fractionation is less than 5 % at magmatic temperature [ref 2].
Zircon preserves the Li isotopic ratio of its parent magma.
(3) Li isotopes largely fractionate when minerals react with water at low temperature [ref 3].
Fractionated Li isotopes would be observed if precursors of zircons reacted with water.

1. Introduction

Why zircon?

There is no rock sample older than ~4.0 Ga. However, differentiated crust and ocean may have formed before 4.0 Ga. Zircons of ~4.0 Ga are the only samples to investigate the Earth's surface environment before 4.0 Ga.

Zircons of >4.0 Ga are the primary Li compositions are preserved after high-grade metamorphism.

2. Analytical Technique

(1) Correlation between Li composition and the pattern of magmatic growth-zoning of Jack Hills zircons suggests Li chemical diffusion in zircon is slow and zircons preserve primary igneous Li composition and information for the origin of their parental magma.
(2) Detrital Li compositions of Jack Hills zircons suggest crystallization from an evolved magma or magma contaminated with surface material as early as 4.3 Ga.
(3) Extremely low 87Li and 7Li argue against diffusion of Li from the grain edge.

References


3. Results

Samples:
Jack Hills zircons: 55 grains (4348 to 3362 Ma)
Mantle derived zircons: Kimberlite, Ocean floor gabbro

CL-Li correlation in Jack Hills zircons

Li mapping:
- Li concentration correlates with CL bands.
- No localized Li hot spot.

Multiplet Li isotope analyses:
- FLI in single growth bands is identical within analytical precision.
- No correlation between 87Li and distance from the grain edge.
No evidence for post-crystallization Li exchange

Adirondack Mts migmatite zircons

MH-92-108-46: Upper amphibolite facies
BMH-01-14-14: Granulite facies
- Detrital core and metamorphic overgrowths from pelitic migmatites have distinct Li abundances.
- Zonation and absence of low 87Li argue against diffusion exchange.

The primary Li compositions are preserved after high-grade metamorphism.

Li substitution in zircons

(1) Xenotime substitution:
(Y, REE)+ + P4+ = Zr4+ + Si4+
(2) Li interstitial substitution [ref 6]:
Li3+ [SiO4] = Zr4+ [SiO4]

(1) only: (REE + Y)P = 1.84 [ref 7]

Li in zircon may be linked to charge-balanced trivalent cations.

4. Discussion

Li abundance in Jack Hills zircons

Li rich (typically >10 ppm)
- Distinct from Ocean crust and Kimberlite-zircons.
- Comparable to zircons from granitic pegmatite and pelitic migmatite.

Most of Jack Hills zircons crystallized in an evolved magma.

Zircons of ~4.3 Ga are enriched in Li

Zircons of ~4.3 Ga have extremely low 87Li
- Distinct from primitive magma (e.g. MORB, OIB).
- Extremely low 87Li is observed in weathered component in continental crust.

Evidence for magmatic recycling of weathered crust formed at low temperature.

Li isotope in Jack Hills zircons

Large variation in 87Li
Extremely low 87Li (< -10 %)

Zircons of ~4.3 Ga have extremely low 87Li

Extremely low 87Li implies the magmatic recycling of weathered crust as old as 4.3 Ga.

5. Conclusions

Li in zircon may be linked to charge-balanced trivalent cations.

The supracrustal 87O is observed in Jack Hills zircons as early as 4.3 Ga [e.g. ref 8]. The Li data is consistent with the O isotope data.