Paleo-Archean generation of the continental lithosphere

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Estimates of the composition of Archean subcontinental lithospheric mantle (SCLM) are largely derived from kimberlite-borne xenoliths. Seismic tomography at regional and local scales shows that kimberlites tend to intrude along the low-Vs zones in and around the high-velocity roots of the SCLM, rather sampling the high-Vs rocks that make up the great bulk of the cratonic SCLM. The high-velocity volumes are best modelled as extremely depleted dunites or harzburgites, analogous to massifs and xenoliths derived from the Archean Laurentian SCLM (and some kimberlite xenoliths). The xenolith sample is strongly biased toward low-Vs lherzolitic material, produced by metasomatic refertilisation of the dunite/harzburgite. The low FeO contents of the depleted rocks (and even most lherzolites) have no analogs in modern tectonic settings, implying that they were generated by processes that were restricted to the Archean. Re-Os analyses of sulfides in Archean SCLM samples worldwide show a major peak around 3 Ga, and none are older than 3.6 Ga. We suggest that the cratonic roots were largely generated in massive high-P melting events (mantle overturns, superplumes, etc.) from 3.6-3.0 Ga, moving Earth into a new tectonic regime. These highly depleted SCLM roots represent a buoyant 'life-raft' that has been essential to the long-term survival of continental crust; before the roots formed, most newly-generated crust would have been recycled on short timescales. Analysis of global Vs tomography suggests that nearly all Archean and Proterozoic shields and mobile belts (with ≥ 70% of existing continental crust) are underlain by this ancient SCLM, variably refertilised during later tectonothermal events.

Oxygen isotopic ratio of ocean zircon

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We have analyzed 196 zircons from 44 samples of plutonic ocean crust and rare serpentinite for $\delta^{18}O$ by ion microprobe to assess what role seawater-altered rocks have in crustal recycling and formation of evolved magmas during crustal accretion. Zircons are from plagiogranite (diorite, qt-diorite, tonalite/trondjhemite), ilmenite±amphibole gabbro, altered veins/dikes in serpentinite, and fault schists collected by submersible and drilling near the 15°20′ (ODP Holes 1270D, 1275D) and Atlantis (IODP Hole 1309D) Fracture Zones on the Mid-Atlantic Ridge, and the Atlantis II Fracture Zone (ODP Holes 735B & 1105A) on the SW Indian Ridge.

The $\delta^{18}O$ of zircon ($\delta^{18}O$(Zc)) with magmatic CL zoning (>90% of spots) define a narrow range (5.19±0.49‰, 2SD; 228 analyses on 196 grains, 2SE=0.03‰) consistent with $\delta^{18}O$ values of igneous zircon in high-T equilibrium with the mantle (5.3±0.6‰, 2SD; Valley et al., 2005 CMP). Within-sample $\delta^{18}O$(Zc) varies by <0.6‰ and rock-to-rock averages differ by <0.5‰, with no correlations observed between $\delta^{18}O$(Zc) and trace elements (e.g., Ti, REE, Hf, Sm/La, Yb/Gd; Grimes et al., in press CMP) in zircon. Average $\delta^{18}O$(Zc) values for different rock types and locations are not distinct: plagiogranites (5.20±0.48‰, 2SD, N=106); ilm±amph gabbro (5.12±0.45‰, 2SD, N=58); serpentinites and fault schists (5.34±0.42‰, 2SD, N=32). The average $\delta^{18}O$(Zc) for the ocean crustal zircon population would be in magmatic equilibrium with normal MORB if $\delta^{18}O$(WR) ~5.7‰ (ΔZc-melt from Lackey et al., 2008 J Pet), consistent with measured $\delta^{18}O$ values for MORB. These observations indicate that the parent melts experienced no detectable contamination by altered rocks. If plagiogranites formed from hydrous partial melting of gabbro, the consistent, mantle-like $\delta^{18}O$(Zc) requires melting and zircon crystallization prior to any water-rock interactions that alter the protolith $\delta^{18}O$.

Rare luminescent (CL) zircon rims with low Ti (<3.5 ppm; uncorr. Ti-in-zircon T = ~70-140°C lower than zircon cores) yield consistently lower $\delta^{18}O$ values (4.79±0.23‰, 2SD, N=15 analyses, 8 grains) than normal ocean crustal zircon due either to 1) lower T crystallization or 2) contamination. We also analyzed occasional zircon with perturbed or chaotic CL zoning and distinctive micro-porosity; these domains contain high [La] and flat LREE patterns, and often overprint oscillatory zoning textures. The measured $\delta^{18}O$ values are highly variable, ranging from 5.1‰ to 0.0‰. These domains appear to be hydrothermal, and reflect alteration and/or precipitation from aqueous fluids.