Cathodoluminescence (CL), isotopic (Pb, O) and trace element zoning in lower crustal zircon documents growth of early continental lithosphere

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Slow diffusion minerals such as zircon offer enormous scope for multi-technique investigation. We have performed coordinated CL imaging and ion microprobe (SHRIMP and Cameca 1280) analysis (U, Pb, O isotopes; multi-element concentrations) of zircon from a granulite facies meta-sediment in the Kapuskasing Uplift of the Archean Superior Province. Most zircons have bright CL (detrital) cores with oscillatory zoning surrounded by darker CL (metamorphic) rims. The very sharp core-rim boundaries locally truncate the primary zoning within the detrital cores, and define rounded crystal tips and abraded/broken edges. The metamorphic rims exhibit ~concentric CL and oxygen isotope zoning around the detrital cores interpreted as growth zoning. Spot profiles document that these detrital cores have $\delta^{18}O$ values of 5.1 to 7.1 permil ($\pm$0.3 to 0.5 permil, 2 sd) and record creation of primitive to increasingly evolved crust from 2.85$\pm$0.02 to 2.67$\pm$0.02 Ga. Metamorphic rims have significantly higher $\delta^{18}O$ values (8.4 to 10.4 permil) and record nearly continuous overgrowth events for ~80 Ma from 2.66$\pm$0.01 to 2.58$\pm$0.01 Ga during high temperature (700^o to 650^{o}C; Ti in Zrc) regional metamorphism. Multi-spot traverses record steep oxygen isotope discontinuities (4‰ over <10μm) at core-rim boundaries that represent a major unconformity in the growth stratigraphy, that culiminated in outer rims formed during first continental rifting (2.51$\pm$0.01Ga). Coordinated CL imaging and micron-scale isotopic analysis have confirmed extremely sluggish rates of volume diffusion of both Pb and O in non-metamict zircon during extended granulite-grade metamorphism (T>650^{o}C for ~80 Ma), thereby introducing a new micro-scale record of the growth and evolution of early continental lithosphere.

Hydrothermal Iron in the Deep Western South Pacific

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Although iron plays an important role as a limiting nutrient for ocean biogeochemical cycles, the difficulty of proper sampling and analysis of this contamination-prone trace element has severely limited data on the oceanic distribution of this element. For example, the most extensive recent compilation of data on Fe in the ocean (Braucher and Moore, 2007) does not contain a single measurement below 1000m in the entire South Pacific. Although iron regenerated from sinking biological debris (including iron originally released from atmospheric mineral aerosols as well as upwelled Fe) is generally thought to be the major source of Fe to the deep ocean, other sources have also been suggested as significant, such as iron from reducing continental margin sediments (Elrod *et al.* 2004). And although it has been known for decades that large quantities of iron are supplied to ocean ridge-crest sediments by hydrothermal activity, it has often been assumed that this iron precipitates near the ridge crest; there has been only one report suggesting that hydrothermal vents are a significant source of Fe for the deep water column at great distances (Wu, 2006). In this presentation, we show the first deep water Fe data from the eastern South Pacific Ocean and demonstrate that hydrothermal vents are a significant source of dissolved Fe to the deep ocean, by analogy to primordial ^3He. Our samples were collected on cruise KM0703 of the R/V Kilo Moana (Station 19, 20°S 170°W) in April 2007. The similarity of the iron profile to $^3He/^4He$ is striking, as is its dissimilarity to the nutrient profiles. <0.4 μm Fe vs. excess ^3He shows a linear relationship with a slope of 9.0 x 10^5 mol Fe/mol ^3He. Our data indicate that <1% of the primary hydrothermal iron survives as "dissolved" iron in the water column at basin scale. Because this small percentage is sensitive to environmental conditions, the contribution from this source may be larger or smaller in the past or future. If all of this hydrothermal iron reached the ocean surface, it would be capable of supplying 30% of the Fe requirement for global ocean primary productivity. Scavenging onto falling particles will reduce this fraction before it reaches the surface, so the actual contribution to primary production ~10%.