Comment on "Zircon Thermometer Reveals Minimum Melting Conditions on Earliest Earth" I
Andrew Glikson, *et al.*
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Watson and Harrison (Reports, 6 May 2005, p. 841) proposed a model for early Earth magmatism based on crystallization temperatures of Hadean zircons. However, detrital zircon populations are skewed relative to the composition of their source terrains, Archaean isotopic and geochemical mantle signatures preclude reincorporation of Hadean continental crust into the early mantle, and the effects of early impacts should be considered.

Watson and Harrison (*1*) used a zircon thermometer based on titanium content to assess Hadean zircons [from >4.0 billion years ago (Ga)] from the Gascoyne Province in Western Australia. They argued that the observed crystallization temperatures (~700°C) are consistent with modern-day geodynamic conditions. On this basis, as well as earlier $^{176}Hf/^{177}Hf$ (*2*) and $^{18}O/^{16}O$ isotope studies (*3*), they suggested that "within ~100 million years of formation, Earth had settled into a pattern of crust formation, erosion, and sedimentary cycling similar to that produced during the known era of plate tectonics." However, the data do not necessarily support that scenario.

Zircon populations of sedimentary mature quartzite yield skewed representations of the composition of source terrains, because zircon survives in preference to corroded mafic and ultramafic-derived sedimentary components. Differential resistance of K-feldspar–quartz assemblages and plagioclase-rich assemblages to erosion, particularly under a high-temperature hydrosphere (*4*) and low pH induced by a CO_2-rich atmosphere, affect estimates of provenance composition. Impact shock–damaged zircons would hardly survive multicycle sedimentary reworking.

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The T_{Zr} values correspond to near-eutectic zirconium saturation temperatures, not to liquid temperatures of parental magmas, which could have included high-temperature equivalents of the Archaean tonalite-trondhjemite-granodiorite suite (TTG) (*5*, *6*). The zircon-poor TTG would be underrepresented in the detrital zircon population. Hydrous low-eutectic magmas do not offer unique fingerprints of tectonic regimes, because adamellite and granite occur in a variety of tectonic settings, including Archaean (3.85 to 2.6 Ga) terrains where TTG is succeeded by late-stage low-eutectic granitoids, Proterozoic mobile belts, and Palaeozoic-Mesozoic orogenic belts. Comparisons between the Hadean and modern Earth (*1*) are inconsistent with the secular evolution of $\delta^{18}O$ in zircons, showing an increased low-T crustal input with time from about 2.6 Ga (*7*), nor do evolutionary trends of ε_{Nd} and ε_{Hf} (*7*) support uniformitarian interpretations.

Constraints on the nature of the pre-4.0 Ga crust are defined by Archaean Nd, Sr, Pb, and REE signatures (*5*–*9*). Had pre-4.0 Ga sial been incorporated into the mantle, Archaean ε_{Nd} values would be expected to be partly or largely negative, which contrasts with the dominance of positive ε_{Nd} values (*9*). Assimilation of subducted pre-4.0 Ga continents is unlikely under high pre-4.0 Ga geotherms, where the gabbro to eclogite transition would be arrested (*10*) and low-density sialic components would return to the upper crust. The factors underlying the original light REE depletion of the mantle remain an open question.

Whereas zircons provide the only pre-4.0 Ga terrestrial remnants known to date, interpretations of the first ~500×10^6 years of crustal evolution need to take into account the effects of the late heavy bombardment (LHB) ~3.95 to 3.85 Ga (*11*), as well as older impacts, required by the early spatial juxtaposition of the Earth-Moon system (*12*). The occurrence of 3.85 Ga banded iron formations in southwest Greenland (*8*) may signify even older mafic volcanism affecting ferrous iron enrichment of the early hydrosphere. The nonrecognition to date of pre-3.8 Ga unmetamorphosed or low-grade metamorphosed rocks may militate for high geothermal gradients. Further discrimination is required between detrital zircons derived from low-T eutectic magmas, TTG-type magmas, and anorthositic magmas. The suggestion that terrestrial zircons >4.0 Ga were possibly derived from impact melt sheets contemporaneous with pre-4.0 Ga lunar mega-impacts [South Pole Aitken, ~2000 km (*13*)] requires further examination.

References and Notes

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