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Observations of Hadean Earth

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The Hadean Eon (4.5-4.0 Ga) is the dark age of Earth history; there is no known rock record from this period. However, detrital zircons as old as nearly 4.4 Ga from the Jack Hills, Western Australia, offer unprecedented insights into this formative phase of Earth history. The observation of a heavy oxygen isotope signature in some Hadean zircons led to the proposal that the protolith of these grains contains ^{18}O-enriched clay minerals which in turn implies that liquid water was present at or near the Earth's surface by ca. 4.3 Ga. The presence of hydrated mineral inclusions of peraluminous character was taken as further evidence of a Hadean hydrosphere. Hadean zircon crystallization temperatures cluster strongly at 680$\pm$25°C, substantiating the existence of wet melting conditions throughout the Hadean and further suggesting an excess of water available during prograde melting relatively close to the Earth's surface. Initial ^{176}Hf/^{177}Hf ratios of Jack Hills zircons ranging in age from 3.96 to 4.35 Ga show surprisingly large deviations from bulk Earth indicating that a significant differentiation of the silicate Earth occurred at $\sim$4.5 Ga. A possible consequence of this differentiation, consistent with the observations above, is the massive formation of continental crust. The inclusion mineralogy of these ancient zircons include meta- and peraluminous assemblages suggestive of two forms of convergent margin magmatism. These data, and the seeming disappearance of the highly hetrogeneous ^{176}Hf/^{177}Hf anomalies by the early Archean, suggest that the Earth had settled into a pattern of crust formation, erosion, and sediment recycling by $\sim$4.3 Ga that is similar in many respects to the known era of plate tectonics. New ideas regarding the feasibility of plate boundary interactions during the Hadean and independent evidence of widespread mantle depletion within 50 m.y. of Earth formation attract comparisons between possible $>$4 Ga plate interactions and the contemporary plate tectonic system. Our data support the view that the Earth almost immediately differentiated into relatively constant volume core, depleted mantle, enriched crust, and fluid reservoirs, and that crust formed at 4.5

Ga had largely been recycled back into the mantle by the onset of the Archean.