Paper Number: 5256

The Earth at 4.1 billion years

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Despite the absence of terrestrial rocks documented to be older than 4 Ga, geoscientists long ago coalesced around the paradigm of early Earth as a desiccated, continent-free wasteland in which surface petrogenesis was largely due to bollide impact into a basaltic substrate and called that era the "Hadean" (hellish time"). But the story emerging from geochemical investigations of >4 Ga Jack Hills zircons is of their formation in near-H_2O saturated meta- and peraluminous magmas under relatively low (15-30°C/km) geotherms. These results have been interpreted as reflecting chemical weathering and sediment cycling in the presence of both liquid water and plate boundary interactions shortly after Earth accretion. Hafnium isotopic data for these ancient zircons requires that their source have been isolated from the bulk silicate Earth by 4.50 Ga in an environment with a $^{177}Lu/^{176}Hf$ ratio as low as 0.01, consistent with modern continental crust, and ruling out a magma ocean phase (or lunar formation) lasting longer than about 70 Ma. Modelling studies show that slow, early plate tectonic-like behaviour yields thermobarometric structures at convergent margins consistent with *P-T* data obtained from inclusions in Hadean zircons and similar in important respects to the modern Himalayan collision. Given general agreement that life could not have emerged until liquid water appeared at or near the Earth's surface, a significant implication of the aforementioned results is that our planet may have been habitable as much as 500 Ma earlier than previously thought. Indeed, C isotopic evidence obtained from inclusions in Hadean zircons is consistent with life having emerged by 4.1 Ga, or several 100 million years earlier that the hypothesized lunar cataclysm.

That our longstanding paradigm is so remarkably inconsistent with results obtained from Hadean zircons is in some ways unsurprising given that it was based on absolutely no observational evidence. However, in context with high expected Hadean heat production and impact flux, it was nearly irresistible to explain the seeming lack of ancient continental crust by its non-existence rather than the equally or more plausible notion that it has been largely consumed by the same processes we see operating on the planet today. Thirty years ago it seemed inconceivable that we might find terrestrial fragments as old as 4.1 Ga but we now know of five locations on the planet with zircons at least this old and many much older. We now possess the tools to undertake an exploration of unprecedented scale by expanding the search for Hadean detrital or inherited zircons to hundreds of Archean quartzites and orthogneisses. Concerns that the Jack Hills zircon record may be unrepresentative of Hadean Earth would potentially be transcended by discovery of numerous geographically dispersed sites that await a global commitment to their exploration.