Evidence for extremely rapid magma ocean crystallization and crust formation on Mars

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The formation of a primordial crust is a critical step in the evolution of terrestrial planets but the timing of this process is poorly understood. The mineral zircon is a powerful tool for constraining crust formation as it can be accurately dated with the U-Pb system and is resistant to subsequent alteration. Moreover, the high concentration of Hf in zircon allow for the utilization of the ^{176}Lu-^{176}Hf decay system to determine the nature and formation timescale of its source reservoir. Ancient zircons with ages of ~4430 Ma have been reported in martian meteorites believed to represent regolith breccias from the southern highlands of Mars [1,2]. We report, for the first time, high-precision Hf-isotope compositions of seven ancient zircons from the NWA 7034 martian regolith breccia that define mostly concordant U-Pb ages with ^{207}Pb/^{206}Pb dates ranging from 4476.3±0.9 Ma to 4429.7±1.0 Ma [3]. This approach guarantees that the Hf isotope compositions were measured on the same volume of zircon for which the ages were determined, thereby ensuring that the initial Hf isotope compositions are accurately time-corrected. Moreover, the age variability of ~50 Myr recorded by the zircons allow us to track the isotopic evolution of their source reservoir. All zircons record unradiogenic initial Hf-isotope compositions inherited from an enriched, andesitic-like crust extracted from a primitive mantle no later than 4547 Ma. Thus, a primordial crust existed on Mars by this time and survived for ~100 Myr before it was reworked, possibly by impacts, to produce magmas from which the zircons crystallized. Given that formation of a stable primordial crust is the end product of planetary differentiation, our data require that the accretion, core formation and magma ocean crystallization on Mars was completed <20 Myr after Solar System formation. These timescales support models suggesting rapid magma ocean crystallization leading to a gravitationally unstable stratified mantle, which subsequently overturns resulting in decompression melting of rising cumulates and extraction of a primordial basaltic to andesitic crust [4].

[1] Humayun, M. *et al.* (2013) *Nature* **503**, 513 [2] McCubbin, M. *et al.* (2016) *JGR* **121**, 2120 [3] Bizzarro, M. *et al.* (2018) this meeting [4] Elkins-Tanton, L. (2008) *EPSL* 271, 181.