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Tidal pull of the Earth strips the proto-Moon of its volatiles

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Prevailing models for the formation of the Moon invoke a giant impact between a planetary embryo and the proto-Earth (Canup 2004, Cuk & Stewart 2012. Despite similarities in the isotopic and chemical abundances of refractory elements compared to Earth's mantle, the Moon is depleted in volatiles (Wolf & Anders 1980). Current models favour devolatilisation via incomplete condensation of the proto-Moon in an Earth-Moon debris-disk (Charnoz & Michaut 2015, Canup 2015, Lock 2018). However the physics of this protolunar disk is poorly understood and thermal escape of gas is inhibited by the Earth's strong gravitational field \citep{Nakajima_Stevenson_2014}. Here we investigate a simple process, wherein the Earth's tidal pull promotes intense hydrodynamic escape from the surface of a molten proto-Moon assembling at 3-6 Earth radii. Such tidally-driven atmospheric escape persisting for less than 1Kyr at temperatures about 1600 K reproduces the measured lunar depletion in K and Na. This result agrees well with with observed enrichment in heavy stable isotopes (Panielo et al., 2012, Wang & Jacobsen 2016) and timescales for the rapid solidification of a plagioclase lid at the surface of a lunar magma ocean (Elkins-Tanton et al., 2011, Tang & Young 2020), but using a completely independent argument. We conclude that tidally driven gas escape is an unavoidable mechanism and that the Moon's magma ocean was about 1600K during its devolatilisation leading to today's volatile depleted composition.