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The first felsic crust: no need for surface water

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The first billion years of Earth's history are critical for understanding the emergence of continents, oceans and the origin of life. Remnants of the earliest felsic crust are preserved in the form of Hadean zircon crystals going as far back as 4.3 billion years. The presence of relatively large quantities of felsic rocks was linked to the existence of liquid water on a planet's surface, however, the mechanism by which early mafic materials became hydrated remains debated. The prevailing scientific consensus is that the earliest felsic rocks formed through the partial melting of mafic material that was hydrated by seawater and subsequently buried by geodynamic processes such as proto-subduction or sagduction. Here, we explore an alternative scenario, proposing that under certain planetary conditions mafic crust may have been hydrated from the beginning without the need for liquid surface water. Under a high-CO_2 atmosphere, water degassing from the magma ocean may have been suppressed, allowing the crystallizing mantle to retain significant water contents, potentially up to 3000 ppm. Likewise, high atmospheric pressure in the aftermath of magma ocean crystallization would have restrained the degassing of water from hydrous partial mantle melts that rise to the surface. Using thermodynamic modeling we show that partial melting of such a hydrated mantle produces H_2O-rich mafic magmas, which then form an early mafic crust intrinsically enriched in water. Melting at the base of such a thick, hydrous mafic crust, or differentiation of newly intruding melts within it, could have led to the generation of granitoids without requiring hydrothermal alteration at the surface. This model offers a new perspective on the origin of the first felsic crust by linking magma ocean crystallization, mantle hydration and early planetary atmospheres. It also suggests that abundant felsic rocks may have formed very early in Earth's history and could also occur on exoplanets where similar magma ocean crystallization processes and atmospheric pressures prevailed.