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An ancient hydrosphere component in the newly discovered ≥4.1 Ga Martian meteorite Teghaza 001

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Most of the surface of Mars has an ancient exposure age of ≥3.7 billion years, however nearly all Martian meteorites are geologically young (≤1.3 Ga) [1]. The only Martian sample with an ancient formation age is a 4.1 Ga orthopyroxenite, a unique rock type amongst all other Martian samples. The other rock with ancient components is a polymict regolith breccia, which was lithified by shock processes as recently as ~1–1.6 Ga. These two samples are crucial to our understanding of early Mars, however due to their mineralogy and modification they provide incomplete links to the ancient Martian crust and mantle.

Teghaza (Teg) 001 is a plagioclase-rich gabbroic diorite and is the first unbrecciated Martian sample with abundant zircons, which have 4.11 Ga U-Pb ages [2]. The mineralogy and geochemistry of Teg 001 suggests that it derives from previously unsampled crust and a unique mantle source compared to all other Martian meteorites. Furthermore, Teg 001 shows evidence for multiple alteration or metasomatism events on Mars, likely corresponding to the ~4.1 Ga U-Pb and Pb-Pb ages recorded by zircons, and overlapping 4.1 Ga Rb-Sr and Pb-Pb ages of silicates and phosphates, respectively [3]. Thus, the crystallization age is likely >4.1 Ga, making Teg 001 the oldest Martian meteorite. The petrographic and geochemical evidence for fluid-rock interactions make it a critical target for evaluating the nature of Mars' ancient hydrosphere.

In this talk, I will discuss water and H isotope compositions of Teg 001 apatite, which indicate mixing or exchange between D-poor mantle water and a D-rich assimilant [4]. The data are placed in context of apatite H isotope compositions from other Martian meteorites, which suggest that the D-rich assimilant in Teg 001 retains an isotopic imprint of the ancient Martian hydrosphere. Collectively, the Martian apatite H isotope data span nearly 4 Ga of Mars' history, providing important clues about the distribution and temporal evolution of volatiles in the Martian mantle, crust, and atmosphere.

[1] Udry, A., et al. (2020) *JGR: Planets*, 125

[2] Liu, Y., et al. (2026) Science (in review)

[3] Saper, L., et al. (2026) Science Advances (in review)