Mars Sample Return: Insights from Martian Meteorites.

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Introduction: Mars Sample Return (MSR) remains the highest priority in Mars exploration in the next decade [1]. The detailed science of an MSR campaign has been considered by the MSR End-to-End International Science Analysis Group [2]. The top scientific objective of MSR is the search for signs of past life; eludicating the planetary-scale geologic evolution of Mars is a close second [2]. Until such time as MSR occurs, Martian meteorites are the only samples of Mars available for research. Their study provides insights into geologic processes not amenable to investigation by landed or orbiting missions, as well as best practices of Mars sample curation, handling, and analysis.

Why Martian meteorites fall short: Studies of Martian meteorites provide a complementary approach to Mars exploration [3]; however, their study has limits [2]. All Martian meteorites are mafic igneous rocks, and the majority date from the younger Hesperian to the Amazonian (1.3 Ga and 200-600 Ma; [4]), with only ALH 84001 from the Noachian (4.1 Ga; [5]). They cannot provide absolute pinning points for the Martian timescale, since their source craters and corresponding surface units have not been identified [3]. Most significantly, the impact delivery mechanism [6] discriminates against weaker rocks, such as sedimentary units and older rocks representing primitive Martian crust and weakened by impacts and aqueous alteration [7]. Furthermore, impact shock may preferentially collapse void spaces [8], forming shock melt pockets and 'sterilizing' the record of low-temperature alteration and weathering.

Why a sample in hand is better than two in the field: Although Martian meteorites may not correspond to the suite of the most desirable rocks for MSR, their detailed study has resulted in significant insights into the geology of Mars that would otherwise remain unknown [3, and references therein], including: primitive mantle reservoirs formed by magma ocean crystallization at ~4.5 Ga and remained isolated until the melting events that formed the 200-600 Ma basalts; carbonate in ALH 84001 formed by percolation of water at the Martian surface at ~3.9 Ga; and the interior of Mars has been an important source of volatiles for the surface, including water but also carbonaceous material [9].

How we keep on preparing: As the only samples of Mars available, studies of Martian meteorites can serve to inform best practices for curation and handling in preparation for MSR; e.g., E2E-iSAG [2] recommends that ways to reduce the amount of returned sample be studied. These studies can be carried out on Martian meteorites today; work being done on the recent Tissint fall (e.g., [10]) is a prime example. In spite of their limitations, Martian meteorites play an essential role in Mars exploration.

References: [1] Squyres S. W. et al. 2011. *Vision and Voyages for Planetary Science in the Decade 2013-2022*. Washington, D.C.: The National Academies Press. [2] McLennan S. M. et al. 2012. *Astrobiology* 12: 175-230. [3] McCoy T. J. et al. 2011. *PNAS* 108: 19159-19164. [4] Nyquist L. E. et al. 2001. *Space Sci. Rev.* 96: 105-164. [5] Lapen T. J. et al. 2010. *Science* 328: 347-351. [6] Head J. N. et al. 2002. *Science* 298: 1752-1756. [7] Walton E. L. et al. 2008. *GCA* 72: 5819-5837. [8] Walton E. L. et al. 2010. *GCA* 74: 4829-4843. [9] Steele A. et al. 2012. *Science* 10.1126/science.1220715 [10] Grady M. M. et al. 2012. *This meeting*.