Constraining the Source Craters of the Martian Meteorites: Implications for Prioritization of Returned Samples from Mars. C. D. K. Herd1, L. L. Tornabene2, T. J. Bowling3, E. L. Walton4, T. G. Sharp5, H. J. Melosh6, J. S. Hamilton1, C. E. Viviano7, and B. L. Ehlmann8,9 1Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, AB, T6G 2E3, herd@ualberta.ca, 2Centre for Planetary Science and Exploration/Department of Earth Sciences, University of Western Ontario, London, Canada, 3Southwest Research Institute, Boulder, CO. 4Department of Physical Sciences, MacEwan University, Edmonton, Canada, 5Arizona State University, School of Earth and Space Exploration, Tempe, AZ, 6Department of Earth, Atmospheric, and Planetary Sciences, Purdue University, West Lafayette, IN, 7Johns Hopkins University Applied Physics Laboratory, Laurel, MD, 8Division of Geological and Planetary Science, California Institute of Technology, Pasadena, CA, 9Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA

Introduction: As the only samples available for laboratory study, the analysis of the >100 known Martian meteorites have resulted in a number of major science advances [1]. However, with the exception of one, the Martian meteorites sample only igneous units [1]. This is because of the inherent bias in the sample delivery method towards young, igneous rocks [e.g., 2]; over 80% of all Martian meteorites are shergottites 575-175 Ma in age [3], some ~14% are nakhlites and chassignites ~1300 Ma [3], and only ~1% are augite-rich shergottites ~2400 Ma [4, 5]. As such, the meteorites are fairly representative of Amazonian igneous activity [1], and could be used to provide pinning points to the relative chronology of Mars based on crater size-frequency distributions [6]. However, a fundamental limitation of the meteorites is that they are randomly sampled from unknown igneous units.

Finding the Meteorite Source Craters: Ejection ages indicate that the martian meteorites were produced by ≤8 impact events between 0.7 and 20 Ma [3]. Attempts at identifying the source craters for these meteorites using spectral matching [e.g., 7] have met with limited success, primarily because the youngest igneous terrains (e.g., Tharsis) are largely obscured by dust [e.g., 8]. The study by [9] was among the first integrated approaches to this problem; however, these authors assumed ages of 4.1-4.3 Ga for the shergottites, a postulation which has since been proven incorrect [e.g., 10]. The identification of rayed craters – indicative of high ejection velocities and young ages – on predominately Amazonian igneous surfaces has provided the best potential candidates [11], although the visibility of rays is also dependent on dust cover.

We have utilized existing remotely-sensed datasets coupled with new modeling of the meteorite delivery process to “rule in” or “rule out” candidate source craters from among a database of the best-preserved craters on Amazonian igneous terrains. Details of the approach, modeling, and initial results can be found in [12]. The main advance we have made is the ability to model the permissible range of crater size for a given meteorite from the shock damage preserved within it.

Results: We selected four martian meteorites which cover the range of petrologic types, Amazonian ages, and conditions and timing of impact ejection: Zagami, Tissint, Chassigny, and NWA 8159 [12]. Cross-reference of the range of permissible crater diameters with our crater database, and selecting for Amazonian-age igneous units and the best-preserved craters, results in a relatively small number of possible craters for each meteorite. All potential source craters except one are < 30 km diameter, consistent with expectations that large, young craters are rare. Eight of the craters could be the source craters for all four meteorites; however, considerations of the differences in petrogenses and ejection ages of the four meteorites shows that each of these meteorites is likely derived from its own crater [12]. Work is ongoing to further refine the potential source craters for each meteorite to a relatively small number [12] (ideally one).

Implications: Uncertainties in the relative chronology of Mars, especially for mid-to late-Amazonian terrains, are up to 2-3 times their actual radiometric ages [6]. Linking the Martian meteorites to their source igneous units will assist in reducing this uncertainty. The priority of MSR can then be on the sampling of Noachian and Hesperian rocks [1], in order to answer fundamental questions related to the geologic evolution of Mars over time [13, 14].