NEW INSIGHTS INTO SOURCE CRATERS FOR THE MARTIAN METEORITES.

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Introduction: The martian meteorites provide invaluable information on the formation, differentiation, and geologic evolution of Mars. With the exception of ALH 84001, they crystallized within the Amazonian: the augite-rich shergottites ~2.4 Ga [1, 2]; the nakhlites and chassignites ~1.3 Ga [3]; and the youngest shergottites 575-175 Ma [3, 4]. Ejection ages indicate that ≤ 8 impact events between 0.7 and 20 Ma produced the martian meteorites [3]. Attempts at identifying the source craters for these meteorites using spectral matching [e.g., 5, 6] have met with limited success. The study of [7] assumed ages of 4.1-4.3 Ga for the shergottites, a postulation which has since been proven incorrect [e.g., 8]. The identification of rayed craters – indicative of high ejection velocities and young ages – on predominately Amazonian igneous surfaces has provided the best potential candidates [9]; however, since the visibility of rays depends on thermal contrast [9], the list of such craters are few and limited. Here we use the preservation of impactites (i.e., impact melt-bearing deposits) as an additional criterion for crater youth [10]. These additional craters, including the rayed craters, will be cross-referenced with the results of new modeling of martian meteorite impact ejection events to further constrain candidate source craters of the martian meteorites.

Modeling: Four martian meteorites were identified for which dwell times and bulk peak shock pressure have been determined (Table 1). These four meteorites cover the range of petrologic types, ages, and conditions of impact ejection. Following [11], we use the iSALE shock physics code [12-14] to simulate the dwell times and peak pressures reached during the ejection of material at greater than escape velocity from a Mars-like basaltic target following a vertical impact at 13.1 km s^{-1}. Model results are then compared to observationally inferred peak pressures and dwell times in order to constrain a size range of possible impactors. Other factors, including pre-impact burial depth, impact velocity, and impact obliquity, will be considered in future refinements to modeling.

Results: Application of the model to the four martian meteorites results in a range of impactor sizes for each; as expected, impactor size correlates with dwell time (Table 1). Impactor sizes are converted to crater sizes based on the formulation of [15]. NWA 8159 results are considered an upper limit, given current uncertainties in the dwell time estimate. The maximum crater size for Tissint is not supported by the shock petrography [16]. These results should be considered preliminary, since e.g., lower obliquity should produce smaller craters by up to a factor of two.

Table 1. Ages, conditions of impact ejection, and modeling results for selected martian meteorites

Meteorite	Crystallization age (Ma)	Ejection age (Ma)	Dwell time (ms)	P, bulk (GPa)	Impactor radius (m)	Crater diameter (km)
Zagami	177 ± 3 [3]	2.92 ± 0.15 [3]	10 [17]	22-23 [17]	781-1250	22-33
Tissint	574 ± 20 [4]	0.7 ± 0.3 [18]	10-20 [16]	≥ 29-30 [16]	685-7692	19.5-164
Chassigny	1340 ± 50 [3]	11.3±0.6 [3]	1-10 [19]	26-32 [20]	63-3824	2.4-89
NWA 8159	2370 ± 250 [2]	0.9 ± 0.1 [2]	100* [21]	15-23 [2]	<7250*	<156*

*considered an upper limit

Discussion: Results demonstrate the potential utility of the model of [11] in narrowing the number of possible source craters for martian meteorites. At face value, our results corroborate the postulation that Tooting crater (28 km) may be the source of younger shergottites [22], and that smaller rayed craters such as Zunil (10.2 km) and Corinto (13.5 km) are excluded. However, smaller craters and narrower ranges are expected as the model is refined.

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