GEOLOGIC MAPPING OF CANDIDATE SOURCE CRATERS FOR MARTIAN METEORITES.

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Introduction: Martian meteorites compose the entire suite of presently accessible rock samples originating from Mars; therefore, they are the only means for Earth-based laboratory research to study the geologic history and evolution of the planet. The sources of martian meteorites are the near-surface units adjacent to craters created by random hypervelocity impacts on the surface of Mars. During its formation, the crater expels local rock such that the sample is able to exceed the escape velocity of Mars [1]. While the search for the source craters for Martian meteorites is not new, some attempts [e.g. 2, 3] have been hampered due to limitations of methodology; recent work considers features that suggest craters were formed recently and produced ballistic ejecta [4,5] in conjunction with meteorite data and impact modeling [6]. Identifying meteorite source craters would provide a vital link between these samples and the geologic units from which they are derived, allowing for more accurate calibration of Mars chronology and essential geologic context for laboratory-based analyses.

Background: Martian craters have been cataloged, described, and classified since Viking [7]. Over time image quality and data availability has improved, leading to improved crater catalogs [8, 9]. Crater catalogs are vital to the search for source craters of martian meteorites and careful mapping is needed to take the next step in confirming the source craters.

Martian meteorites are biased towards Amazonian crystallization ages and show young ejection ages of <20 Ma [10]. This information, compiled with modeling of meteorite delivery to determine a range of permissible crater sizes and other remote sensing data, allow for the refinement of potential source craters [6]. We employ multiple methodologies to identify martian meteorite source craters. This involves utilizing a subset of the database of the best-preserved craters by [5]: specifically, those occurring on Amazonian volcanic terrains [11, 12], and cross-references its attributes with martian meteorite ejection age and source crater diameter from impact modeling based on shock parameters [6]. We have updated the database into a SQL server, which is queried with the above parameters to identify candidate source craters for a given martian meteorite.

Initial results for four igneous martian meteorites (Zagami, Tissint, Chassigny, NWA 8159) indicate <20 potential source craters for each of the four meteorites [6]. This number has since expanded to include craters marked as a “3” on the preservation scale of [5] and is continually being refined. The candidate source craters, as determined by being the most well-preserved and located on Amazonian igneous terrain are mapped in ESRI ArcGIS. This mapping allows for detailed description of these potential source craters and to determine their relationships to the igneous units that they sample (Table 1).

Here, we present preliminary geologic mapping of crater 09-000015 [9] in ArcGIS, using morphologic mapping techniques similar to [14]. Our mapping focuses primarily on the volcanic context of the crater, determining the degree of preservation, and the temporal and spatial relationships between the crater, ejecta blanket, and surrounding volcanic flows.

Crater 09-000015 is ~19.2 km in diameter, located ~400 km northeast of Ascraeus Mons. Cataloguing performed by [9] using a THEMIS Daytime IR mosaic provided information on its size, topographic, mor-

Table 1. Locations, sizes, dust coverage, relative ages, and surface units of candidate source craters for martian meteorites

Crater Name	USGS ID[a]	Latitude	Longitude	Region	Diameter (km)	TES DCI[b]	Preservation[c]	Degradation[d]	Skinner ID[e]	Tanaka ID[f]
Zunil	15-000240	7.7	166.19	Elysium	10.2	0.94	5	4	Aps	lAvf
Corinto	15-000165	16.95	141.71	Elysium	13.5	0.945	5	4	Ael1	AHv
Domoni	02-000116	51.4	234.41	Alba	14	0.95	5	3	Hal	AHv
Unnamed	09-000015	19.28	260.07	Ascraeus	19.6	0.934	5	3	At5	AHv
Unnamed	03-000082	44.62	253.02	Alba	21.2	0.95	4	4	Aau	AHv
Unnamed	09-000007	17.98	249.11	Ascraeus	22.2	0.948	4	4	At5	AHv
Tooting	08-000060	23.18	207.78	Amazonis	28.9	0.939	5	4	Aa3	AHi
Unnamed	03-000205	32.64	254.05	Alba	12.2	0.94	4	3	Nf/NHcf	AHv

Notes: [a]Data source from [9]. [b]Dust Cover Index (DCI) of the crater shown as a deviated value from 1 where 1 is considered dust-free [13]. [c,d]Relative preservation of the crater as defined by [5,9], respectively – Preservation is scaled from 1-5 with 5 being the most well-preserved and degradation is scaled from 1-4 with 4 being the most well-preserved. [e,f]Surface unit as described by [11,12], respectively.

phometric, and morphologic data. The crater floor to the average rim elevation is 1.22 km [9]. Crater 09-000015 has a well-defined ejecta blanket but secondary craters have not been mapped in detail. Multiple ejecta layers are observed [9] but the ejecta appears homogeneous due to high dust cover, creating challenging conditions for mapping. Both [9] and [5] identified the central feature of the crater as complex, pitted and well-preserved.

Approach: Images of crater 09-000015 and the surrounding area were incorporated into ArcGIS; the images include full coverage with context camera (CTX), and limited High Resolution Imaging Science Experiment (HiRISE) coverage over a Mars Orbiter Laser Altimeter (MOLA) basemap. Thermal inertia based on Thermal Emission Imaging System (THEMIS) data is excluded due to poor data quality for this region. Images were added to ArcGIS and further processed to rectify any geographical inconsistencies. Additionally, basic measurements of adjacent lava flows are taken to determine widths and lengths of the visible flows.

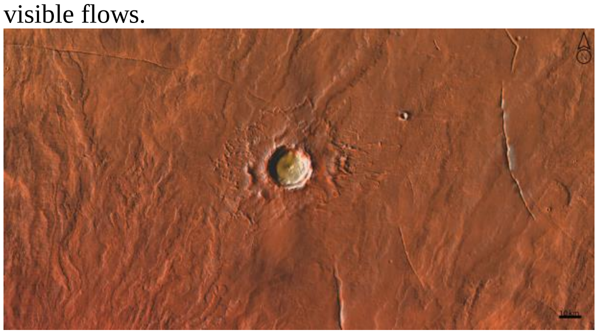

Figure 1. THEMIS Day IR with colour from MOLA topography of crater 09-000015. Day IR is chosen despite thick dust coverage because it best contrasts adjacent lava flows.

Results: The ejecta blanket crosscuts adjacent lava flows and appears to be crosscut by a graben running east-west (Fig. 1). Additionally, not all of the lava flows appear to be crosscut by the graben, suggesting volcanic activity that is more recent than both the formation of the graben and the crater. However, recent volcanic activity in Tharsis has a relatively low effusive rate [6] making this an unlikely scenario. Instead, the appearance of these crosscutting relationships are likely a result of thin ejecta layers superimposing the graben and flows. This ejecta is thin enough that it does not completely obscure the underlying features. Large flows adjacent to the crater travel southwest-northeast nearly in line with the center of Ascraeus Mons. These flows typically range in width from ~1-8 km and can be upwards of 100 km in length. Ascraeus Mons is most likely the source for these lava flows rather than Alba Mons to the northwest. Alba Mons is nearly three times the distance from the crater and the flows are not radial to it. These elongated flows are commonly found in the Tharsis Montes formation and are morphologically similar to flows of terrestrial basalt [11].

Implications and Future Work: Initial mapping indicates that crater 09-000015 is consistent with the constraints of a candidate source crater for one or more of the martian meteorites as suggested by the database query. The next stages of mapping will include searching for secondary crater rays, analysis of the crater walls to determine if layers are present, and evaluation of the surrounding dust cover for potential applications of spectral matching. Expansion of mapping to other candidate source craters is underway. Thermophysical rays in martian craters signify secondary crater chains formed by high-velocity ejecta at low ejection angles and subsequently decelerated to below escape velocity [4]. A minor part of this ejecta includes lightly shocked material arising from spallation – a key process in the meteorite delivery process [1] – and suggests that rayed craters are a probable source for martian meteorites [4]. However, candidate source craters are not required to be rayed, because rays may not be visible due to lack of thermal contrast with the surface [4]. Layers in the crater walls will be useful in understanding which martian meteorites should be grouped as part of the same ejection event. Because some martian meteorites share similar ejection ages, it has been suggested that these groups source from the same ejection event [e.g. 10, 15]. However, because lava flow thickness can vary and the four meteorites analyzed in [6] suggest burial depths of 50 m or less, layers in the crater walls are essential to evaluate this argument. Evaluation of dust-free areas within the crater or nearby lava flows is underway allowing for spectral matching as an additional method of constraint [16].

References: [1] Melosh H. J. (1984) *Icarus, 59,* 234-260. [2] Ody A. et al. (2015) *Icarus, 258,* 366-383. [3] Werner S.C. et al. (2014) *Sci, 343,* 1343-1346. [4] Tornabene L. L. et al. (2006) *JGR: Planets, 111,* E10006. [5] Tornabene L. L. et al. (2012) *Icarus, 220,* 348-368. [6] Herd C. D. K. (2018) *LPSC XLIX,* Abstract #2266. [7] Carr M. H. et al. (1977) *JGR, 82,* 4055-4065. [8] Barlow, N. G. (1988) *Icarus, 75,* 285-305. [9] Robbins, S. J. and Hynek B. M. (2012) *JGR Planets, 117,* E05004. [10] Nyquist L. E. et al. (2001) *Space Sci Rev, 96,* 105-164. [11] Scott D. H. and Tanaka K. L. (1986) *USGS Misc. Investigations,* Map I-1802-A. [12] Tanaka K. L. (2014) *Planet. And Space Sci, 95,* 11-24. [13] Ruff S. W. and Christensen P. R. (2002) *JGR: Planets, 107*(E12), 2-1. [14] Mouginis-Mark P. J. and Boyce J. M. (2012) *Chemie der Erde – Geochemistry, 72,* 1-23. [15] Lapen T. J. et al. (2017) *Sci Advances, 3,* e1600922. [16] Viviano-Beck C. E. et al. (2017) *LPSC XLVIII,* Abstract #2800.