GLOBAL MARTIAN CATALOGUE OF RAYED CRATERS AS POTENTIAL SOURCES FOR MARTIAN METEORITES.

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Introduction: Planetary science is reliant on a wide variety of data, most of which are collected remotely and at coarse spatial scales. Mineralogical exploration of a planetary surface using these remotely collected data requires some sort of groundtruth in the form of samples that can be directly analysed in laboratories here on Earth. In the case of Mars, the only such samples we have are a small number of meteorites. These rare stones can share with us a wealth of information about the Martian atmosphere and surface. However, to date no consensus has been reached as to where on the planet these samples have come from. Discovering the exact source region(s) for these rocks would have important implications for Martian science.

Broad candidate source locations can be identified based on two primary factors: 1) the relatively young crystallisation ages of most of the meteorites, and 2) the minimum size of crater that would have been created by an impact energetic enough to eject pieces of the surface out of Mars's atmosphere and gravitational influence. A third additional constraint that can be incorporated is the recent ejection ages of all the meteorites. Impacts can create a distinctive pattern of radial rays of material around the resulting crater. This pattern degrades with age and is thus an indicator of a young crater. Various authors [1 – 4] have identified numerous rayed craters on the surface of Mars large enough to have ejected material, using day and nighttime THEMIS imagery, however a complete global survey has not previously been undertaken. A global survey of rayed craters ≥ 3 km diameter is presented here for the first time and used together with other remote sensing datasets, including global dust coverage and geological unit ages, to identify potential source craters for the Shergottite martian meteorites that could be further investigated through high resolution VNIR spectral imaging.

Methods and Datasets: THEMIS day and night images covering ± 60° latitude were loaded into ArcGIS together with the Robbins & Hynek crater database [5]. All craters in the database within this latitude constraint with a minimum circular diameter of 3 km were examined in both THEMIS datasets for signs of rays. Three criteria were defined to measure each crater against: 1) at least one ray must be a minimum of 2 crater diameters in length, 2) rays must occur in more than one quadrant of the crater surrounds, 3) rays must be visible as albedo difference against the surrounding terrain only and not texturally variant. If a crater satisfied all three in either the day or night imagery it was added to the rayed crater catalogue. A confidence rating was assigned to each crater in the catalogue indicating how confident the classification of rayed is, with lower confidence ratings primarily being due to poorer THEMIS image quality (e.g. Fig. 1).

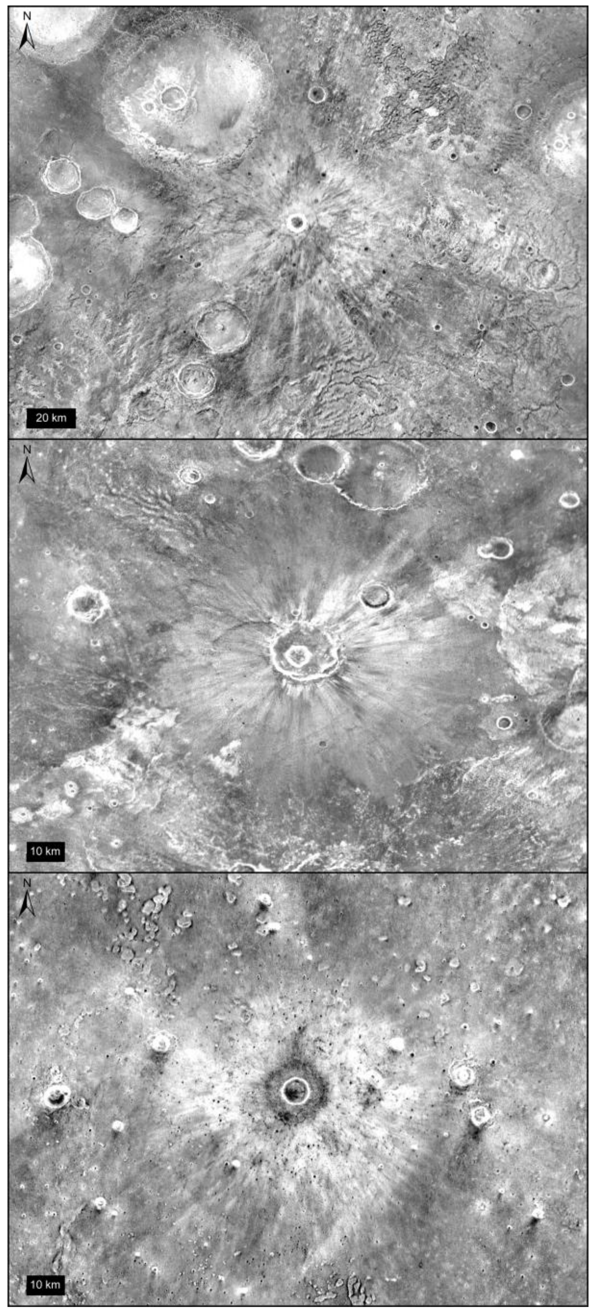

Figure 1. *Examples of newly-identified rayed craters in THEMIS nighttime images. Approximate locations (in °) top to bottom are:-19, 349; -35, 231; 18, 118.*

Results: A total of 71,925 craters were surveyed resulting in a rayed crater catalogue containing 118 individual craters (Fig. 2). A number of these have been identified as rayed in previous works and are noted as such. This catalogue was then used as a starting point to identify some potential source craters for the Martian meteorites.

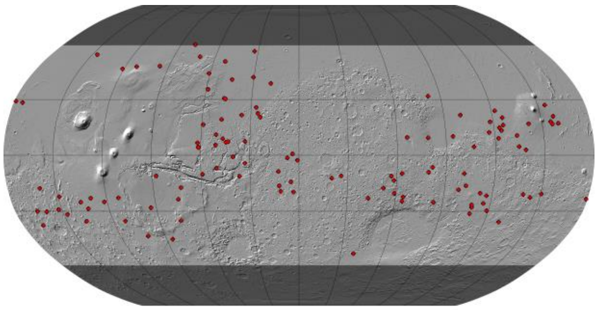

Figure 2. *Global map of rayed craters ≥ 3 km diameter. Grayed regions are >60° latitude, and were excluded from survey due to the quality of THEMIS data.*

Identifying source craters: Shergottites. This catalogue can be used together with other remote sensing datasets of the Martian surface, and mineralogical and petrological details from the Martian meteorites, to narrow down potential source craters for further study. In the case of the Shergottites they are generally accepted to have crystallized approximately 175 – 475 million year ago [6] during the Amazonian epoch. 27 rayed craters lie on terrain identified as Amazonian and Hesperian in the Tanaka et al [7] geological map. The Shergottites are predominantly igneous in mineral composition showing little sign of significant in-situ alteration and therefore volcanic units are likely source units. Of the 27 Amazonian and Hesperian terrain, rayed craters 15 are on volcanic units.

Thermal infrared data can give information on the mineral composition of the Martian surface but on area scales that are coarse (i.e. the Thermal Emission Spectrometer (TES) global mineral abundance maps have a 3-km pixel size). To get mineral composition information on smaller size scales requires shorter wavelengths from Visible and Near Infrared instruments such as the Compact Reconnaissance Imager for Mars (CRISM) onboard Mars Reconnaissance Orbiter. Where the ubiquitous Martian dust layer is thick instruments such as CRISM cannot see enough of the bedrock underneath to identify its constituent minerals. Using the TES [8] and OMEGA [9] dust coverage maps those craters that could be further investigated using VNIR data were identified, narrowing down the 15 volcanic terrain rayed craters to just 6 in the southern Tharsis region (Fig. 3).

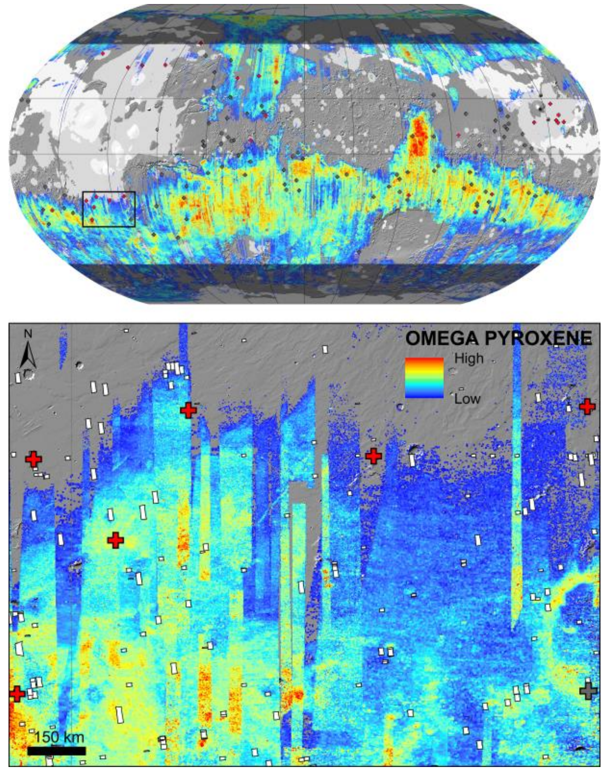

Figure 3. *Refining potential source craters for martian meteorites. (Top) Global OMEGA pyroxene map (used here as a proxy for dust-free regions), with white and light gray areas representing Amazonian or Amazonian/Hesperian units [7]. Box shows location of bottom image. (Bottom) Six rayed craters in the Southern Tharsis region of correct age that have good coverage in GRS, TES and OMEGA data. Map shows relative pyroxene content from OMEGA [9]. Also shown are CRISM targeted footprints as of January 2018.*

Future Directions: The 6 rayed craters identified in the southern Tharsis region will be investigated in more depth using all available CRISM images and resulting mineralogy compared to that from the Shergottite class of meteorites. Similar studies can be performed using the rayed crater catalogue as a starting point for the other classes of Martian meteorites.

References: [1] Werner S. C. et al (2014) *Science*, *343*, 1343-1346. [2] Kereszuti A. & Chatzitheodoridis E. (2016) *Orig. Life Evol. Biosp*. [3] Tornabene L. L. et al. (2006) *JGR*, 111, E10006. [4] Gregg T. K. P. (2015) *LPSC XXXXVI*, Abstract #2442. [5] Robbins, S. & Hynek, B. (2012) *JGR*, 117, E06001. [6] Jones, J. H. (2015) *MPS*, *50*, 674-690 [7] Tanaka, K. et al. (2014) *USGS Investigations*, 3292. [8] Ruff, S. W. & Christensen, P. R. (2002) *JGR*, 107, 5127. [9] Ody, A. et al. (2012) *JGR*, 117, E00J14.