Characterizing Rock Abundance at ExoMars Landing Site Candidates

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Introduction

The European Space Agency’s ExoMars programme comprises the Trace Gas Orbiter and Rover/Surface Platform missions. At the 3rd ExoMars Rover Landing Site Workshop (October 2015, ESTEC, Noordwijk, The Netherlands) 4 candidate sites were presented and assessed based on their scientific merit and compliance with engineering and environmental constraints [1].

We here present preliminary work to gather representative float rock abundances for each candidate site. Float rocks are individual fragments not associated with continuous outcrop.

Manual rock count method

500 × 500 m count areas were defined in HiRISE map-projected JP2. Locations were selected to adequately sample geologic diversity and maximize spatial coverage within landing ellipses.

Human counters evaluated features that they identified as rocks that cast shadows in the solar illumination direction by drawing circles that completely enclose features.

Areal coverage fraction, $F_a$, was calculated for each count area. $F_a$ is an upper limit on actual areal coverage by resolvable features, because 1. Excess area is included in the calculation and 2. Intersection of circles is possible for close features.

Rock abundance model

Rock abundance (RA) is often quantified as cumulative areal fraction (CFA), here represented as $F_a$ of a surface covered with rocks of diameter $\leq D$.

The canonical rock distribution model [4] was established by fitting an exponential curve to the CFA occupied by rocks at the Viking landing sites.

The small rock population ($D \leq 1$ m) observed in the immediate vicinity of the near and far-field image mosaics was found to fit well to the relationship:

$$F_a(D) = k e^{-q(k)D}$$

where, $q(k) = 1.79 + 0.152/k$ and $k$ is the rock abundance factor.

$k$ can be retrieved for a given rock size distribution by minimizing residuals in a fit we employ a least squares fit.

Typically the model is used in conjunction with thermally-derived RA, orbital image, geological inferences, and available in-situ results to infer rock SFDs [5, 6], to constrain the abundance of small rocks that are unresolved in orbital images.

Caveats

The model suffers from a lack of validation at large rock diameters due to the small area visible from landed craft.

Common metrics of rock abundance such as CFA do not constrain rock shape or state of burial.

Results

Areal Dorsum

Hypanis Valles

Mawrth Vallis

Oxia Planum

Repeat counts

Counts repeated in the same area by different counters illustrate differences in consistency of identification, e.g. for ESP_039747_1880 in Aram Dorsum:

- Discrepancies between counters occurred most frequently in three cases:
  1. In areas of shadow casting rocky outcrop, where isolated float rocks are difficult to distinguish from outcrop.
  2. At diameters close to the resolution limit, and at large diameters, where outcrop can be confused with partially buried boulders.
  3. In areas where local topography (e.g. wrinkle ridges) imposes changes in solar illumination angle, and therefore shadow length, of features.

Thermally-derived rock abundance

Rock abundance derived using anisothermality in IR datasets requires assumptions regarding the SFD, and the number of thermally distinct components that contribute to the signal [7].

Use of thermal RA therefore requires constraint of thermal contributions from different features and terrain types. Thermal RA may be an upper limit for $F$ from float rocks, because thermal contributions from float rocks are only a part of the signal, with both rough and smooth outcrop also contributing [8, 9]. The extent to which outcrop poses a hazard/obstacle to the lander and rover depends on the slope distribution.

Discussion/Conclusions

Observed CFAs appear not to match well with any single model curve. It remains to be demonstrated that the family of curves employed in [4] can represent rock SFDs at sites with geologic histories dissimilar to those that formed the Viking landing sites.

Despite caveats regarding human consistency, variable illumination conditions, and classification, rock SFDs for float rocks may still be used for relative ranking of hazardous rock abundance at each site, because isolated float rocks are some of the most easily distinguishable and uniquely hazardous of surface features.

The use of high resolution thermal data [10], super-resolution imaging techniques [11] and detailed geological inferences may be key in ongoing assessment of ExoMars Rover candidate landing sites.

References