Nearest Neighbor Analysis, Regression, and Secondary Crater Prospecting on Mars

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Introduction

The only way of constraining regional surface ages on Mars at present is through the impact crater size frequency distribution system developed by [1], [2], [3], and [4], among others (Fig.1). Over-representation of sub-kilometer craters implies that surface age estimates could be inflated in imagery with fine spatial resolution.

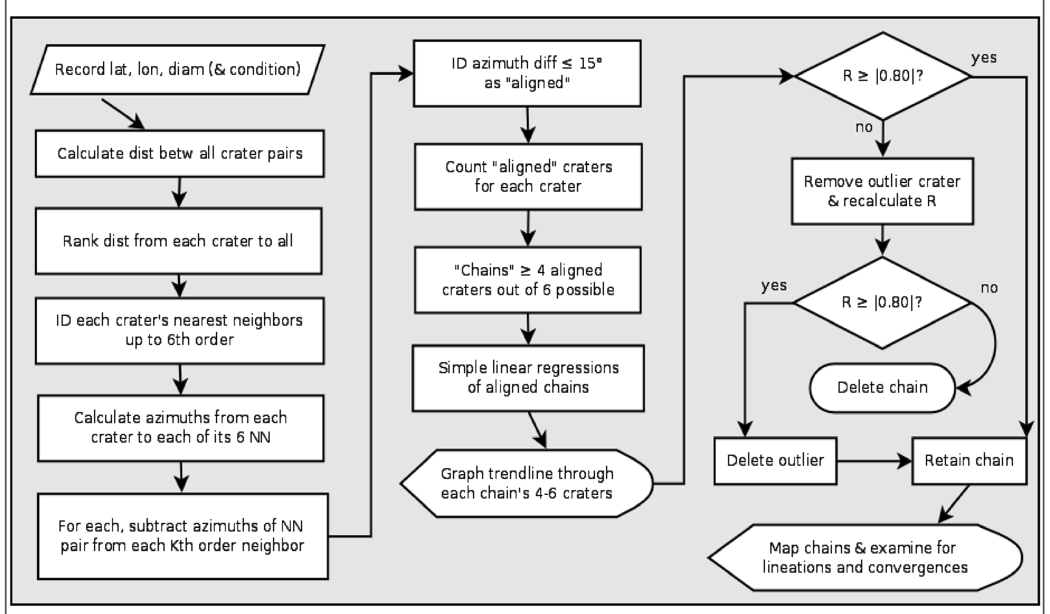
Secondary cratering has been put forward to explain such over-representation [5]). Previous attempts to deal with it have included segmenting the size-frequency curve [4] or examining craters for irregular shapes and lineations [6].

This paper proposes a variant on nearest neighbor analysis, combined with regression, to prospect for lineations among small craters in a region. The method identifies candidates for missing ray structures at least for near-field secondaries. It focuses subsequent geomorphic investigation to exclude alternative causes for lineations.

Data and methods

Image source. MGS MOC Narrow Angle image (PIA02680), 2 March 2006, Terra Sabæa, near 21.9S and 338.6W, in an area characterized by Noachian plateau dissected and ridged units [7]. The image covers ~ 3 km by 6.6 km at 1.5 m/pixel resolution. A 900m x 900 m area in the north corner was processed as follows (Fig.2).

Fig. 2: Summary of data processing steps



Testing for randomness in azimuth differences. To screen for randomly generated alignments, "aligned" and unaligned azimuth differences for each crater were compared with expected counts from the binomial distribution, using the X^2 goodness-of-fit test. The tightest cutoff angle to produce significance < 0.05 was **15°**.

Final selection of aligned crater chains. Crater chains were retained as alignments if regression yielded an R ≥ |0.80| (sometimes after outlier removal), yielding 32 chains with **71 aligned craters** out of the 146 craters in the database or 48.6%.

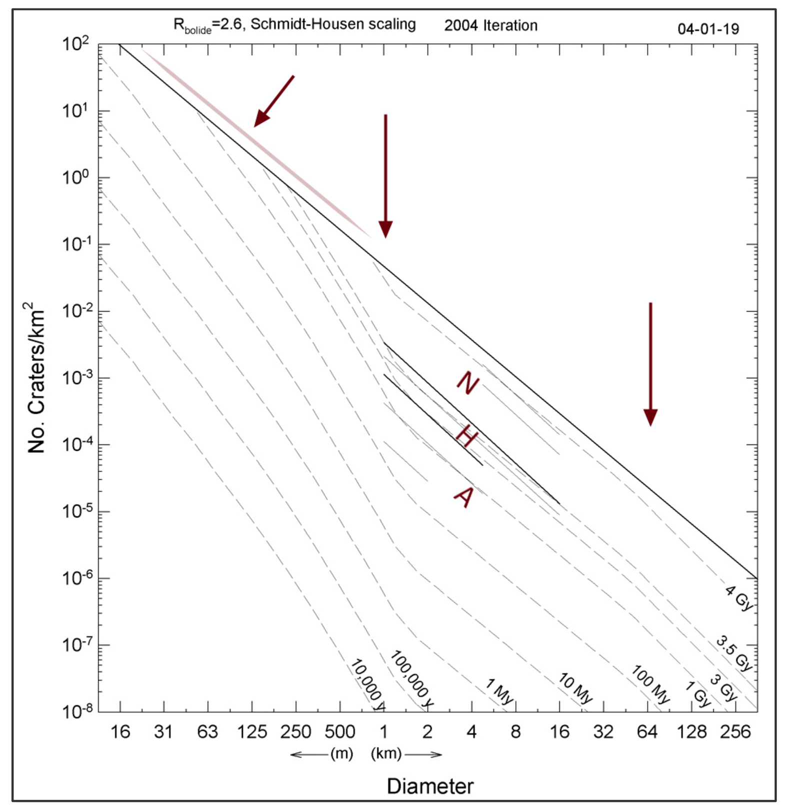


Fig. 1. Crater diameter and frequency distribution with inflection points ~64 km, 1 km, and 100 m

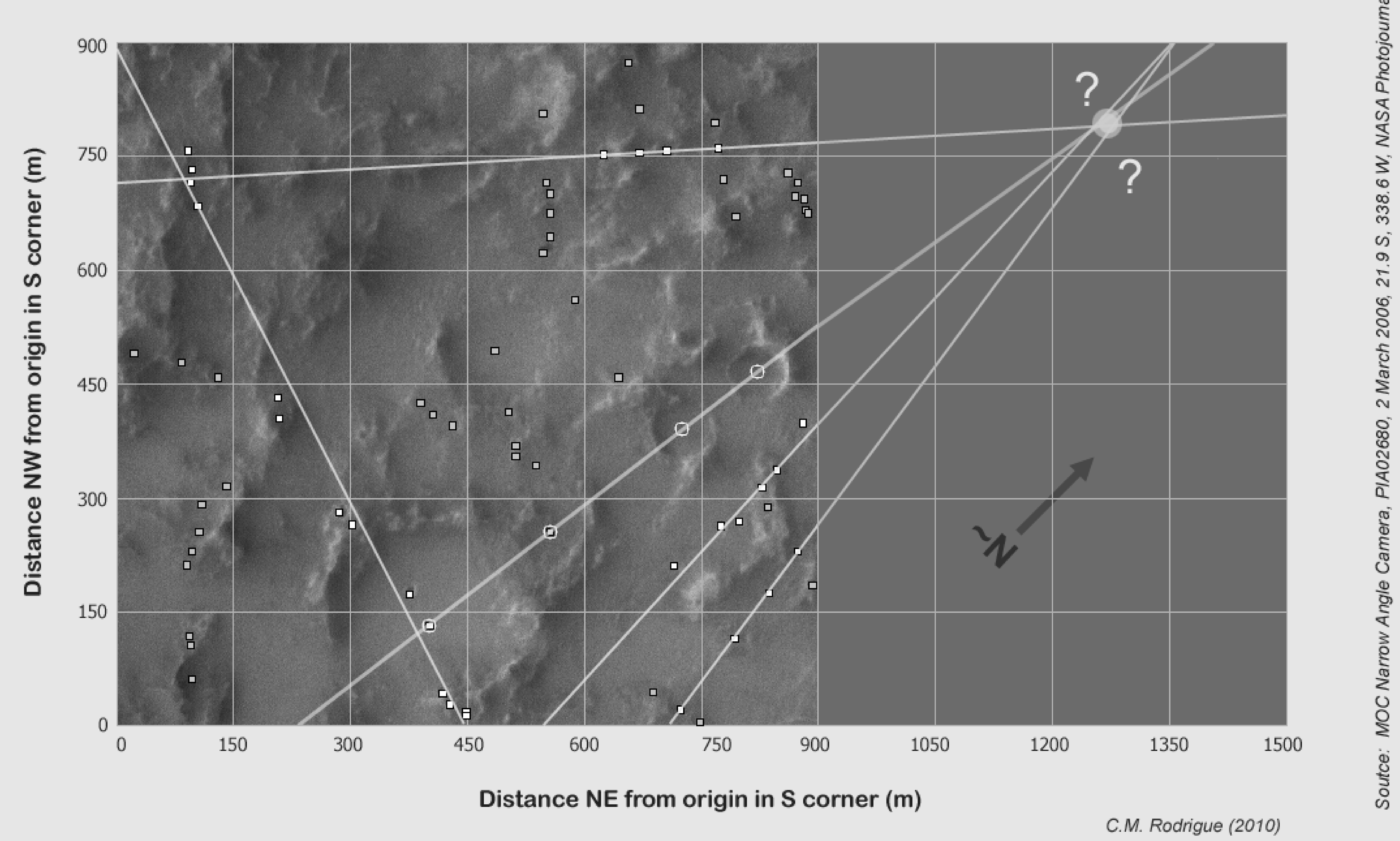
Results

- The map of short alignments of neighboring craters identifies *potential* secondary crater chains (Fig. 3)
- Several alignments are themselves lined up along the south and west of the image.
- Three other short chains converge to a point ~400 m off the image to the north.
  - Unfortunately, imagery of comparable resolution is not available for that adjacent area.
  - Visual inspection of the craters in the study area turned up a fourth line of larger craters.
  - Plotting their trajectory leads to intersection with the other 3 lines in the same vicinity.

Discussion

- Lineations identified in this way represent ***candidates*** for secondary crater ray structures.
- These require follow-on geomorphic analysis to eliminate alternative explanations for lineation, such as:
  - A catena of sinkholes in a region subject to extensional stresses
  - A chain of rootless cones of phreatomagmatic origins
  - A random alignment of craters of such different ages that they cannot be attributed to a single larger impact
- In this particular area:
  - The first alternative is inconsistent with the presence of wrinkle ridges, which indicate a past or present compressional stress field in the region [7]
  - The second alternative would be surprising here, as rootless cones are mainly found in the Northern Lowlands
  - The third alternative remains viable pending further work

Fig. 3.



Conclusions

This method does readily identify candidate chains and thereby focuses the search for alternative explanations for these lineations. It also helps bound the estimation of the prevalence of secondary cratering at the smaller end of the crater frequency and size relationship. In the current case study, nearly half the craters were in lineations consistent with secondary cratering.

Once these many candidates are sieved for lineations arising from alternative processes, the remaining estimates of secondary cratering could experimentally be removed from crater counts and the constants in the power law relationship re-estimated empirically. Would their deletion remove or reduce the inflection at the sub-kilometer size range?

Future plans include:

- Performing the method on an area of known secondary cratering (e.g., Lyot Crater)
- Adding crater condition to the database (secondary craters from a single event should be similar in erosion/apparent age)

References

[1] Arvidson R. et al. (1978) Standard Techniques for Presentation and Analysis of Crater Size- Frequency Data. NASA [2] Tanaka K.L. (1986) JGR 91, 139-158. [3] Neukum G. and Ivanov B.A. (1994) in Gehrels, T. (ed.) Hazards Due to Comets and Asteroids, 359-416. [4] Hartmann W. and Neukum G. (2001) Space Sci. Rev. 96, 165-194. [5] Preblich et al. (2007) JGR 112, E05006. [6] McEwen A.S. et al. (2005) Icarus 176, 351-381. [7] Scott et al. (1987) Maps I-1802 A, B, & C. USGS. [8] Fagents et al. (2002) LPS XXXIII, Abstract #1594. [9] Lanagan et al. (2002) LPS XXXIII, Abstract #1694.

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