SPATIAL ANALYSIS OF ROOTLESS CONE GROUPS ON ICELAND AND MARS. B. C. Bruno[1], S. A. Fagents[1], T. Thordarson[1], and S. M. Baloga[2], [1]HIGP, University of Hawai'i, 2525 Correa Road, Honolulu, HI 96822 (bruno@higp.hawaii.edu), [2]Proxemy Research, 14300 Gallant Fox Lane, Bowie, MD 20715.

Introduction: This paper examines the spatial distribution of cones within several Icelandic rootless cone groups (RCG's) in order to: (1) better understand the underlying processes governing cone distribution (e.g., the relative roles of lava tube distribution and substrate hydrology); and (2) develop a remote sensing tool to identify RCG's on Earth and other planets. Of particular interest is Mars, where potential RCG's have been identified (Fig. 1). If confirmed, they have important implications for the presence of water (or ice) on Mars.

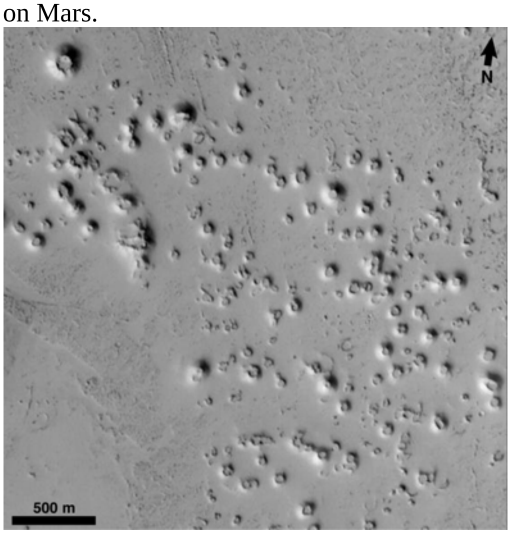

Fig. 1. Candidate RCG in Amazonis Planitia, Mars

Rootless cones are hydrovolcanic cones of spatter and scoria that rest directly on tube-fed pahoehoe lava flows (Fig. 2). They are typically stratified, inversely graded and capped with welded spatter (indicating cessation of explosivity due to volatile depletion). Some cones have multiple craters. Cone morphology and spatial density vary significantly among RCG's, with cones typically being tens of meters in diameter.

Data: The current data set consists of four RCG's in South-Central Iceland and two candidate RCG's on Mars. The Icelandic groups are: (1) Innri-Eyrar, (2) Hnuta, (3) Blagil (all associated with the 1783-84 Laki lava) and (4) Landbrot (associated with the 934-40 AD Eldgja lava). The Martian groups are both located in Amazonis Planitia.

Methods: This analysis uses two methods to independently assess the degree of spatial randomness within a cone field and to evaluate the statistical confidence in this assessment.

Method 1: Nearest Neighbor (NN) analysis [1] quantifies the characteristic spacing among points within a given spatial area. The key parameters are R (the ratio of the mean actual distance between a point and its NN to that expected of a random (Poisson) distribution) and c (a confidence estimate in the departure from randomness). Randomly distributed cones have R~1, whereas R<1 indicates aggregation. R>1 indicates that cones tend to form away from existing cones, with Uniform distributions (i.e., maximum spacing) having maximum R.

Method 2: The Chi-Squared Goodness-of-Fit test determines if a given dataset is likely to be produced from random sampling of a population with a specific distribution (e.g., Poisson or Uniform). It outputs two parameters: degrees of freedom (df) and a test statistic (U), which is compared to a critical chi-squared value.

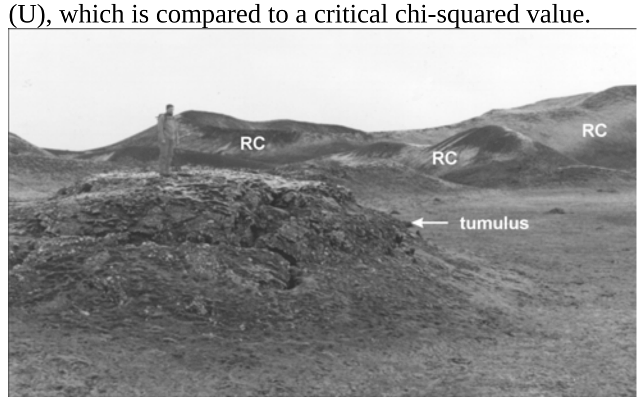

Fig 2. Field photo of Laki Innri-Eyrar, a typical RCG in South-Central Iceland.

Results:

Table 1. *Nearest Neighbor Analysis*

RCG	**N**	***R***	***c****
Blagil (Laki, Iceland)	87	0.87	2.4
Innri Eyrar (Laki, Iceland)	80	0.80	3.5
Hnuta (Laki, Iceland)	660	0.68	15.5
Landbrot (Eldgja, Iceland)	1282	0.77	15.5
N. Amazonis (Mars)	129	0.85	3.2
S. Amazonis (Mars)	282	0.84	5.1

*c>1.96 indicates result is significant at the 0.05 level.

Table 2. *Chi-Squared Fit to Uniform Distribution*

RCG	**df**	**U**	**Critical value**	**Uniform?**
Blagil	7	23.7	14.1	Reject
Innri Eyrar	7	31.9	14.1	Reject
Hnuta	15	127.1	25.0	Reject
Landbrot	20	302.0	31.4	Reject
N. Amazonis	8	15.7	15.5	Reject
S. Amazonis	11	36.1	19.7	Reject

Table 3. *Chi-Squared Fit to Poisson Distribution*

RCG	**df**	**U**	**Critical value**	**Poisson?**
Blagil	9 (6)	60.9 (13.2)	16.9 (12.6)	Reject (Reject)
Innri Eyrar	6	28.2	12.6	Reject
Hnuta	10	254.5	18.3	Reject
Landbrot	10	141.5	18.3	Reject
N. Amazonis	7 (6)	10.9 (8.7)	14.1 (12.6)	Fail to reject (Fail to reject)
S. Amazonis	9 (8)	17.2 (7.1)	16.9 (15.5)	Reject (Fail to reject)

( ) denotes grouping of neighboring probabilities to eliminate empty bins.

Discussion: *Icelandic Rootless Cone Groups*

Nearest Neighbor analysis yields low *R* (0.68-0.87) for the four Icelandic RCG's (Table 1), i.e., the cones are more aggregated than would be expected from a Uniform or Poisson distribution. Chi-squared testing confirms that neither the Uniform (Table 2) nor Poisson (Table 3) distribution fits the Icelandic data. All results are significant at the 0.05 level.

Cone aggregation implies that any substrate volatile depletion must be highly localized (so as not to prevent another cone from forming nearby). Moreover, it indicates that cones preferentially form near existing cones, and may suggest that multiple cones are formed along a single (or bifurcating) lava pathway. One possible scenario is upstream crack propagation following lava subsidence (Fig. 3), consistent with the observed upflow stacking of overlapping cones [2,3].

An ANOVA indicates that the *R* values of three of the four Icelandic RCG's are statistically indistinguishable at the 0.05 level. The Hnuta cone group shows a higher degree of clustering, perhaps due to its geological setting. Hnuta is relatively low in elevation (i.e., water-rich sediments may be thicker), and located just upflow of a ridge (i.e., lava may have thickened before crossing the ridge).

Are the Martian cone groups likely to be rootless?

The *R* values of the two Martian cone groups in Amazonis Planitia are statistically indistinguishable from the Icelandic cone groups (except Hnuta), lending support to their candidacy as RCG's. The chi-squared goodness-of-fit confirmed that the Martian cone groups do not have a uniform distribution (Table 2); a bin sensitivity analysis showed that these results are robust (not dependent on bin selection).

However, the chi-squared goodness-of-fit test to the Poisson distribution can not independently confirm that the Martian RCG's are more aggregated than would be randomly expected. In one case (S. Amazonis; see Table 3), the result was dependent on bin selection and therefore not conclusive.

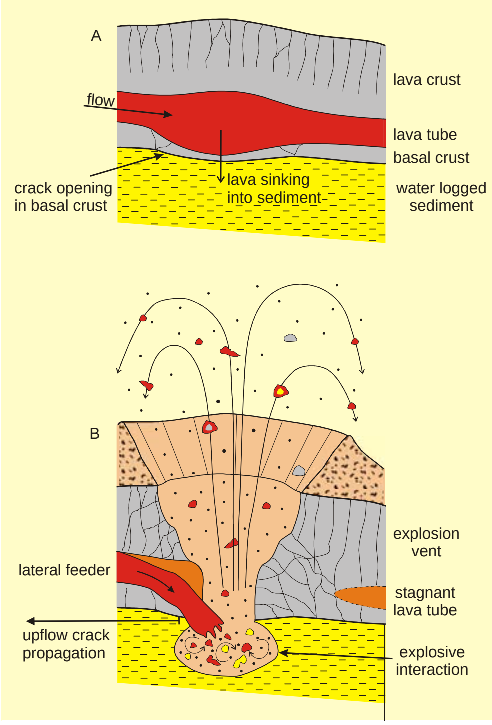

Fig.3. Schematic of rootless cone formation.
(A) Tube-fed lava sinks into the underlying sediment. Cracks develop in the basal lava crust, initiating contact – and explosive interaction – between the lava and the water-logged sediment. (B) The explosive event precludes further lava flow movement (and therefore further rootless cone formation) in the downflow direction. However, rootless cones may form upflow, perhaps facilitated by upflow crack propagation.

Preliminary Conclusions: The four Icelandic rootless cone groups each show significant (non-random) clustering. This clustering indicates that any substrate volatile depletion associated with cone formation is highly localized, thus allowing later cones to form nearby. Nearest Neighbor results indicate the two Martian cone groups studied have a similar spatial distribution to the Icelandic groups studied, supporting their candidacy as rootless cone groups.

References: [1] Clark, P. J. & F. C. Evans (1954), *Ecology, 35 (4)*, 445–453. [2] Thordarson, T. (2000), in Volcano/Ice Interactions of Earth and Mars, Univ. Iceland Press. [3] Fagents, S. A. & T. Thordarson (2003), in The Geology of Mars (Chapter 8), Cambridge Univ. Press.