SPATIAL ANALYSIS AS A DISCRIMINATOR: RESULTS FOR THREE ADDITIONAL TYPES OF MESOSCALE MOUND AND RAISED RIM MORPHOLOGIES. D. M. Burr[1] B.C. Bruno[2,3], S.M. Baloga[2] and L.S. Glaze[2] [1]Carl Sagan Center, SETI Institute (515 N. Whisman Rd. Mountain View, CA 94043 USA. dburr@seti.org) [2]Proxemy Research, Bowie, MD, USA. [3]Hawaii Institute of Geophysics and Planetology, University of Hawaii, Honolulu, HI, USA.

Introduction: Mesoscale (~100-meter-scale) mounds and raised rim depression (MRRDs) of various origins are found on Earth and Mars. Examples include secondary craters, rootless cones, mud volcanoes, and collapsed pingos. Each of these MRRD types has a very different formation mechanism and different implications for water on Mars. Differentiating these features remotely through morphology is often difficult. However, statistical analysis of their spatial distribution has shown utility in differentiating among three MRRD types: Icelandic rootless cones, Arctic ice mounds (pinogs), and Martian pedestal impact craters [1,2]. Here we expand on our technique and apply it to three additional types of terrestrial MRRDs. Our goal in providing analyses of terrestrial MRRD populations is to aid in correctly identifying MRRDs on Mars. First, we discuss the statistical technique. Then we summarize each MRRD type formation mechanism. Finally, we present our results.

Spatial Analysis Technique: The spatial analysis technique is discussed in [1,2]. Briefly, the technique quantifies the spatial distribution of features within a feature field as $R = R_a/R_e$, where R_a is the actually average distance between nearest neighbors, and R_e is the expected average distance for a random distribution. $R < 1$ indicates points are clustered relative to a random distribution, whereas $R > 1$ indicates points are relatively dispersed. Any random probability distribution may be used to develop a statistical test on R. Following conventional nearest-neighbor analysis, we used the nearest-neighbor distribution derived from the Poisson distribution [cf. 3]. This form of randomness suggests that there were no physical interactions during the formation of the individual geologic features. Departures from Poisson randomness suggest that the formation of one feature influenced the formation of other features, for example, due to resource depletion [4]. The significance of R_a is evaluated by the test statistic $c = (R_a - R_e)/\sigma_{Re}$ where σ_{Re} is the standard error of the mean NN distance for the Poisson nearest neighbor distribution. $|c| > 1.96$ indicates a statistically significant departure from randomness in the Poisson sense at the 0.05 level.

Rootless cones and collapsed pingos have similar R and c values [1,2]. Thus, skewness and kurtosis were examined as possible discriminators between these two types of MRRDs [2]. Given that the images used in these prior analyses have a range of resolutions (3-74 m/px), we re-examined those data to assess the influence of resolution. Six selected feature fields were analyzed at varying degrees of image resolution (degradation), with the R, c, skewness, and kurtosis computed at each stage. Although R and c values varied with resolution, in no case did that variation affect the final interpretation [5]. Neither were they significantly affected by the trimming technique. Trimming is a standard procedure in exploratory data analysis [e.g., 6,7] that involves deleting data in the tails (e.g., 2.5% on each side) of the observed distribution. The procedure is designed to expedite the evaluation of the key features of the distribution. We used a 5% asymmetric (high-end) trim [cf. 2]. Whereas R and c values did not vary significantly with resolution or trimming technique, the skewness and kurtosis values did vary enough with resolution as to affect the final interpretation. Higher resolution data gave consistently lower skewness and kurtosis values than low resolution data (Fig. 1). Thus, those measures are not used here.

We also developed an additional approach to determine the effect of other (linear) features on the distribution of (point) features in a field. One of our data sets had roads running through the population of MRRDs. Thus, our specific interest was to evaluate whether or not the road could be the cause of the apparent departure from spatial randomness for that population (Table 1, 'Odessa pop.'). To make this evaluation, we have compared the statistical distribution of actual distances from each MRRD to the nearest road with those distances predicted by a hypothetical Poisson-based distribution. The dramatic dissimilarity between these distributions (i.e., log-normal for actual versus uniform for random) is highly suggestive that accessibility or other factors represented by the roads could be dominating the nonrandom test results. Only further ground truthing or additional data (e.g., from aerial photos) could provide definitive resolution. This approach for evaluating the effect of linear features on point features will be used in on-going work exploring the correlation of Alaskan pingos with faults [cf. 8].

MRRD types: We group the MRRDs by origin.

Hydrovolcanic. Hydrovolcanic MRRDs are those created by interaction of lava with surface or near-surface water. Rootless cones in Iceland result from interaction of tube-fed lavas with surface or near-surface water [9; spatial analysis in 1,2]. Littoral cones in Hawaii result from interaction of channel- or tube-fed lava with seawater [10,11]. Basaltic ring structures (BRSs) are the product of lava-water interaction and subsequent scour by catastrophic floods [12 and references therein]. We analyzed two distinct populations of BRSs in the Channeled Scabland catastrophic flood tract, located near the towns of Odessa and Tokio, Washington State, USA [12].

Sedimentary. MRRDs formed by sedimentary diapirism include mud volcanoes, which result from density contrasts leading to overpressurization of fine-grained material [summarized in 13]. We analyzed a population of subaerial mud volcanoes from the Absheron Peninsula, Azerbaijan [see 13 for more information].

Icy. Ice MRRDs can result from either surficial or ground ice. Massive ground ice-cored mounds, known as pingos, subsequently collapse, leaving raised-rim depressions in (formerly) periglacial regions [15; spatial analysis in 2]. Surficial ice can produce MRRDs from deposition of glacial [16], glaciolacutrine, or glaciofluvial [e.g., 17] ice blocks. We analyzed a population of glaciofluvial kettle holes on the Skeiðarásandur outwash plain, southern Iceland.

Results/conclusion: Table 1 provides our results, to be presented in context with previous and anddi-tional analyses [18]. This work extends previous suggestions [1,2,4,19] that spatial distribution analysis can be used to discriminate the nature of small geologic features when morphologic evidence is ambiguous. More comprehensive methods of analyzing the statistics of nearest neighbor distributions [4] can be used to delineate parent probability distributions other than the Poisson. When applied to MRRDs or other geologic features, this may provide more than a diagnostic of feature type. Depending on population size and the extent and regularity of the geologic setting, the identification of parental probability distributions provides a basis for determining physical interactions between the features during their formation and constraining modes of formation.

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Figure 1: Effect of resolution on skewness, kurtosis.

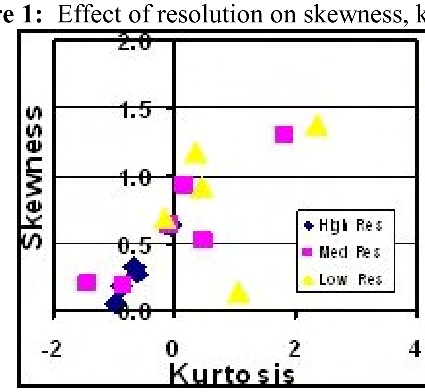

Table 1: Nearest neighbor analyses in this work

Type of MRRD	Statistical Results			
HYDROVOLCANIC	**ROI (km^2)**	**#**	**R**	**|c|**
BRS · Odessa pop. · Tokio pop.	 348,863 277,905	 143 28[2]	 0.76[1] 1.12	 5.26 1.00
SEDIMENTARY				
Mud volcanoes	63,744	196	0.67	8.59
ICY				
Ice-block forms · glaciofluvial	 1,297,988	 728	 0.81	 9.89

[1]Additional analysis of the Odessa population strongly suggests that the presence of roads is a dominant factor in the apparent clustering.

[2]The low number of features in this population renders these results inconclusive.