A STATISTICAL ANALYSIS OF CORONA TOPOGRAPHY: NEW INSIGHTS INTO CORONA FORMATION AND EVOLUTION.

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Introduction: Extensive mapping of the surface of Venus and continued analysis of Magellan data have allowed a more comprehensive survey of coronae to be conducted [1]. Our updated corona database contains 514 features, an increase from the 326 coronae of the previous survey [2]. We include a new set of 106 Type 2 or 'stealth' [3] coronae, which have a topographic rather than a fracture annulus [1, 3]. The large increase in the number of coronae over the 1992 survey results from several factors, including the use of the full Magellan data set and the addition of features identified as part of the systematic geologic mapping of Venus. Parameters of the population that we have analyzed to date include size and topography [1, 4].

Method. The updated corona database presents a unique opportunity to perform rigorous statistical analysis, as it contains a large amount of data that come from a well-defined population. Because the data are so voluminous and of such high quality, conclusions based on statistically significant results are definitive. Our initial analyses of the expanded corona population has already produced some new scientific results [4]. As an example of what can be learned from the dimensional information in the corona database, we performed a strict hypothesis test to determine if the Type 1 and Type 2 coronae widths are statistically 'the same'. Because both population widths have classic lognormal distributions, the hypothesis test was conducted on the geometric means for the two classes of coronae. The Type 1 coronae have a geometric mean diameter of 221.5 km with a corresponding 95% confidence interval of 209.8 – 233.9. The Type 2 coronae have a geometric mean of 208.2 km with a corresponding 95% confidence interval of 190.0 – 228.1 km [4]. The amount of overlap between the confidence intervals of the two populations indicates that the mean values cannot be distinguished statistically. We conclude that there is statistically no difference between the distributions of corona diameters, and we infer that the Type 1 and 2 coronae come from the same population [4].

The distribution of widths for the combined Type 1 and 2 coronae are strongly lognormal. The classic lognormal character suggests that the physical processes responsible for corona formation are operating over a limited scale, and that there might exist a continuous, but limited, range of subpopulations. It is these subpopulations that we hope to identify, as they may provide insights into both the processes responsible for corona formation and the nature of the Venus interior.

Smrekar and Stofan [5] classified coronae into ten morphologic subgroups. Thus, we can intercompare these subgroups to determine if there is any systematic behavior that sets one or more of these subgroups apart from the others. Before statistical comparisons can be made, we must first determine the probability distributions that best describe each of the topographic group data sets. This is critical, as most hypothesis tests assume data that are normally distributed. The subgroup data are all non-normal in character. Our experience has shown, however, that hypothesis tests can still be performed by using appropriate data transformations. We begin, therefore, by transforming the data in each subgroup by taking the natural log. This transformation results in roughly normal distributions for every subgroup, despite the fact that some subgroups are sparsely populated. To test whether or not the normal distribution is appropriate for the transformed data, we conducted a set of rigorous χ^2, goodness of fit tests on each subgroup for $\alpha = .05$. Because the results of the χ^2 hypothesis test are dependent upon binsize [6], we have taken into consideration a variety of approaches to optimal binning [6, 7]. Based on these tests, we concluded that the normal distribution cannot be precluded for the transformed data sets, with the exception of group 6, which had too few members. Therefore, we can proceed with comparative analyses and hypothesis tests.

The approach we have taken to compare the subgroups is to calculate the 95% Bonferroni confidence intervals around the mean for each subgroup. Bonferroni intervals take into account the reduced degrees of freedom resulting from the simultaneous estimation of means and standard deviations for multiple data sets [6]. Coronae that are depressions, rimmed depressions and domes (groups 4, 8 and 1) tend to be smaller. Coronae that are plateaus, rimmed plateaus, or have rims surrounding central domes (groups 2,3a, 3b and 5) tend to be larger. This is consistent with the model predictions of Smrekar and Stofan [5], in which later-stage coronae (depression and rimmed depressions) are smaller due to the inward migration of the delaminating ring. These findings are inconsistent with a spreading drop model [8], which predicts larger depressions as a plume head approaches the surface and spreads. As the plume head spreads out, it produces a sequence of morphologies. For a sufficiently buoyant plume the sequence is: dome, plateau, rimmed plateau, rim only, and rimmed depression.

Topographic Analysis. In order to further identify corona subpopulations, we measured a number of key parameters for the Type 1 and 2 corona populations. For each feature, the Magellan altimetry data were used to measure basal altitude, maximum height, minimum depth (for depressions), maximum rim height, rim width. The first parameters chosen for analysis were a comparison of maximum height to topographic group for Type 1 coronae. For groups 4 and 7 (rimmed depressions and rim only features), maximum rim height was equivalent to maximum height.

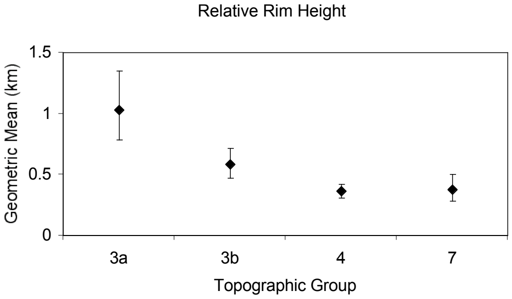

Figure 1. A plot illustrating the analysis of topographic type to maximum height for Type 1 corona topographic groups. 95% Bonferroni intervals are shown.

Analysis of Figure 1 suggests that Type 3a coronae (rimmed plateaus) are significantly topographically higher than group 3b (rims with central topographic high), group 4, and group 7. Group 3b is distinctly larger than group 4, while group 7 overlaps in height with groups 3b and 4.

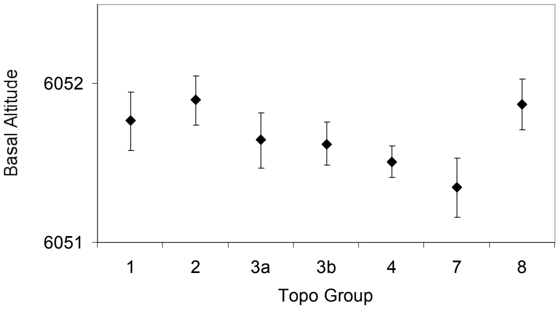

Figure 2. A plot of basal altitude vs. topographic group for Type 1 coronae. 95% Bonferroni intervals are shown.

We have also begun an analysis of the topographic group vs. basal altitude for Type 1 coronae (Fig. 2). Groups 2 (plateaus) and 8 (depressions) occur at basal altitudes significantly higher than groups 4 and 7. Group 1 is also significantly higher than group 7. Groups 3a and 3b overlap all other groups.

Conclusions. Our initial application of statistical analysis to the corona database has provided new insights into corona formation [4]. We are now extending that analysis to include detailed corona topography. Our initial results suggest that the heights and basal altitudes of coronae differ between some corona topographic groups, which we are comparing to current models of corona fomation and evolution.

Our next step is to compare the maximum height of the corona rim and interior to corona type (Type 1 vs. Type 2), topographic form, width, rim width, and geologic setting using statistical analysis. We have previously predicted that the lack of a fracture annulus coincident with the topographic rim at topographic coronae could be caused by several factors: 1) a weak lithosphere due to high heat flux; 2) a very strong lithosphere, such that there is a small curvature and thus low stress at the surface; and 3) slow viscous bending (low strain rate) [1]. We favor option (3), which would also result in lower rim heights. We are also in the process of assessing the amount of volcanism at each corona, will compare this data to other corona parameters.

We anticipate that applying these sophisticated analysis tools to specific types of coronae, such as Type 2 coronae, will help to constrain the particular causes for the great variations observed in corona morphology. We also expect this analysis to yield results for coronae in particular regions, such as along Parga Chasma.

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