A NEW STUDY OF SHIELD FIELDS AND THEIR SPATIAL RELATIONSHIPS ON VENUS. Rebecca M. Hahn[1] and Paul K. Byrne[1], [1]Planetary Research Group, Department of Marine, Earth, and Atmospheric Sciences, North Carolina State University, Raleigh, NC 27695 (rhahn@ncsu.edu).

Introduction: The Magellan spacecraft was the first mission to map virtually the entire surface of Venus using synthetic aperture radar (SAR) [1–3]. This SAR imagery was subsequently used to identify and classify volcanic features and structures across Venus far beyond the extent of earlier missions [4,5]. These data revealed a planetary surface covered in volcanic edifices of a range of sizes, as well as a number of volcanic landforms unique to Venus including coronae, arachnoids, and novae [4,6]. One of the most abundant and geographically widespread types of feature across Venus are small shield volcanoes. These edifices are typically <20 km in diameter and <1 km in height [7–9]. Shields that are highly concentrated in approximately equidimensional areas are termed "shield fields," and are typically a few hundred km in diameter [4,10]. The clustering of these shields indicates continuous or episodic small-scale eruptions through numerous discrete sources within contiguous areas [4,9,11]. Our research seeks to better understand the spatial relations between edifices within these shield fields, as well as the relations between shield fields and surrounding features (e.g., rifts, coronae, ridges, etc.)—on a global scale.

Data and Methods: To build upon previous volcanic features catalogs [e.g., 12] we have developed a new global survey of Venusian volcanic edifices with the Magellan SAR FMAP (full-resolution radar map) left- and right-look global mosaics at ~100 meter-per-pixel (m/px) resolution. Our completed dataset includes ~85,000 edifices, 98% of which are volcanoes <5 km in diameter (**Figure 1**).

This global catalog includes 32,435 shields we categorize as "well-defined volcanic edifices" that are <5 km in diameter (green triangles in Fig 1). This categorization follows earlier studies for Venus [e.g., 2,4,6,13], i.e., a landform that has a quasi-circular planform and is approximately conical, with one side more radar-bright than the other (consistent with being illuminated from a single radar-look direction). Our catalog also includes an additional 51,634 edifices <5 km in diameter that are more difficult to robustly identify (e.g., these features have poorly resolved summit craters or bases) because of variable quality of the SAR data, but which we include for completion (teal triangles in Fig 1).

Previous studies focused on single (or only a few) shield fields and defined those features empirically (e.g., on the basis of mapping by a single worker). To establish a *global* database of shield fields, we developed a set of quantitative criteria that led to two such catalogs: one that includes all 84,069 edifices <5 km in diameter, and one that only includes the 32,435 "well-defined volcanic edifices."

For each of these catalogs, we used the Aggregate Points tool in ArcGIS Pro to group edifices that are within 0.4 decimal degrees (~45 km) of one another. This distance value was informed by previous work that described the range of sizes of shield fields [4,10]. A 1-km buffer was then created around the output polygons from the Aggregate Points tool, to connect polygons that shared a common vertex (i.e., they shared a common edifice) and so avoid a given edifice being counted twice; this step also served to incorporate any edifices on the boundaries of the polygons.

The Minimum Bounding Geometry tool then created the smallest polygon encompassing all the points that were grouped together from the Aggregate Points

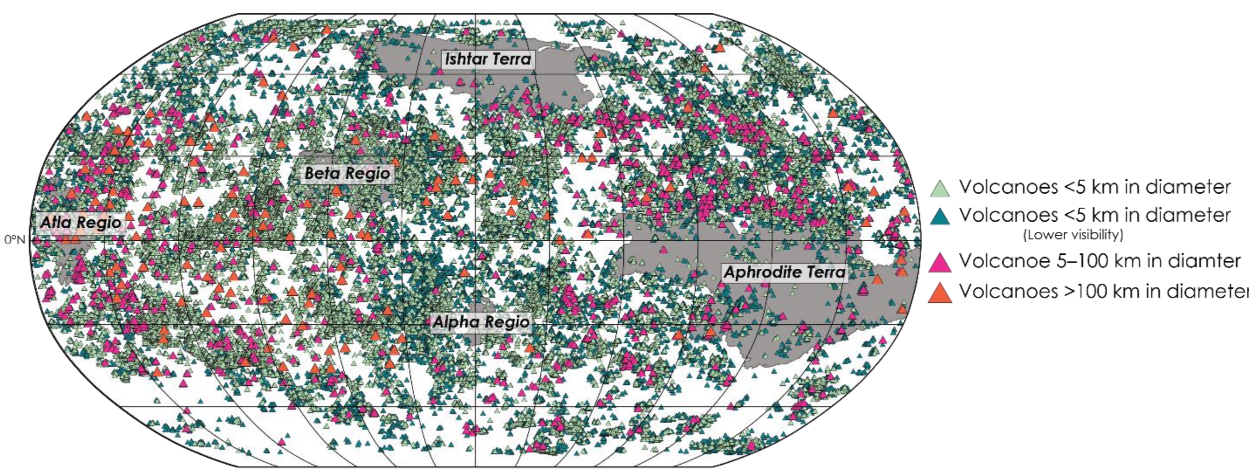

Figure 1: Global survey of volcanic edifices on Venus. This survey includes more than 85,000 volcanic edifices that span virtually the entire planet. Outlines of major Venusian physiographic features are shown in grey for geographic context.

tool. Finally, any polygons that contained fewer than 20 edifices were removed. This lower limit was, again, informed by previous studies [14], and also by considering minimum sample-size values for subsequent statistical analysis. We found 194 and 742 shield fields globally for well-defined and for all edifices, respectively.

Following the creation of the global shield fields datasets, we created a batch-process model in ArcGIS Pro ModelBuilder for determining summary and spatial statistics within each shield field. Summary statistics include the mean and maximum number of edifices per field, as well as the standard deviation. The spatial statistics include nearest-neighbor analysis to determine whether the edifices are randomly distributed or clustered within each field, and directional distribution analysis to determine if there is a specific orientation of volcanoes in a given field.

Results: We compared our results with earlier work [e.g.,4,14,15] to ensure our methods identified shield fields within the same location and of approximately the same size as those described previously (**Figure 2**). Based on these comparisons, we determined that our automated method for delineating shield fields returns viable results, a summary of which is given in **Table 1**. Results from the average nearest-neighbor analysis indicate an average *r* value of ~1.0, implying a generally random distribution of shields <5 km in diameter within each shield field. Even so, we find that some shields are slightly more dispersed, and others are slightly more clustered, than random. The causal relations between those fields with clustered edifices and nearby tectonic systems (e.g., rifts) and other volcanic features (e.g., coronae) remains to be established.

	Well-Defined edifices (n = 32,435)	Entire Edifice population (n = 84,069)
Summary Statistics		
# of shield fields	194	742
Mean shield field diameter (km)	190	209
Mean # of shields within field	40	48
Max # of shields within field	255	624
Nearest-Neighbor Statistic (NNS) for all shield fields		
Mean NNS	1.0195	1.047
Max NNS	1.5355	1.5383
Min NNS	0.6720	0.6929

Table 1: Initial statistical results for global database of shield fields on Venus. Nearest-Neighbor Statistics (NNS) return *r* values, where *r* = 1 is randomly distributed, *r* >1 is dispersed, and *r* <1 is clustered [16]. Resulting *p-values* and *z-scores* indicate that we are unable to reject the null hypothesis that the data are randomly distributed.

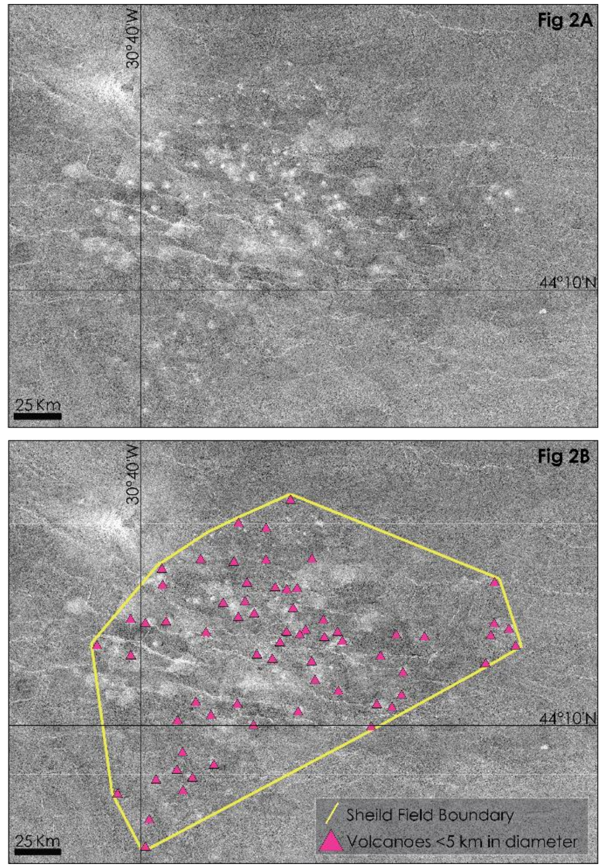

Figure 2: Comparison with earlier work of our automated shield field detection routine. A) A shield field identified by Addington (2000) centered at 44.61° N, 329.8° E. The entire image is ~230 km across. B) That same shield field identified by our automated approach. The boundary we find is outlined in yellow and is ~180 km in diameter, with constituent edifices shown in pink

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