

MORPHOLOGY AND POSSIBLE VOLCANIC ORIGIN OF SUB-KILOMETER DOMES IN THE ARRHENIUS REGION, MARS

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Overview: Mapping part of an extensive field of sub-kilometer domes in the Arrhenius Region of Mars has revealed characteristics similar to some terrestrial volcanic fields. Important for this recognition is the identification of a veneer of sediments whose erosion by aeolian deflation has exposed the domes. There is compelling evidence to support a fracture control for emplacement of the domes because elongate dome diameter orientations are nearly identical to those of fractures and a trough in the area. In a volcanic context the two most plausible models for this dome field are cinder cones and table mountains; the choice is dependent upon identifying the time of dome emplacement relative to deposition of the sediments.

Introduction: The 36,000 km² Arrhenius Region is located in the southern hemisphere of Mars east of Hellas Planitia between 235° and 240° east longitude and 40° to 45° south latitude. Several terrestrial analogs previously have been proposed to explain the origin of the sub-kilometer domes in this region. These include: diatremes [1], cinder cones [2,3,4], table mountains [2], pingos [5] and pseudocraters [2,6,7,8]. The domes likely formed during the Amazonian Era [1], which began approximately 1.8 billion years ago. Since then, a variety of processes may have dramatically altered the appearance of this region. For example, extensive aeolian erosion and deposition occurred during the Noachian and Early Hesperian periods in the southern hemisphere [9].

In this study, we rigorously test the volcanic origin hypothesis by comparing statistical and morphological data from domes in the Arrhenius Region with several terrestrial volcanic dome fields [10]. The data utilized in this study were obtained from digital images of Mars acquired by the Viking Orbiter missions. The images have resolutions ranging from 173 meters per pixel to 32 meters per pixel. To make the most accurate measurements we elected to focus our study on two frames, 586B34 and 586B36 (34 and 36), an area where a greater portion of the individual domes are more visible above the surrounding sediments.

Methods: Frames 34 and 36 were mapped in order to develop an understanding of the regional geomorphology and stratigraphy. Understanding the regional geology is important for constraining the types of factors that might affect interpretation of dome morphology. It is particularly important to determine whether or not the domes are partially buried by surrounding sediments.

In our study area, 649 domes comprising numerous dome clusters were identified as either elliptical or circular in shape. For those that appeared circular one diameter was measured. Those that appeared elliptical were measured along the length of both their long and short axes. The ratio between the short and long axis, also known as the aspect ratio or ellipticity ratio, of each elliptical dome was calculated. In addition, the orientation of each long axis was recorded. Other data collected include percentages of domes with central pits, spatial density of the domes to determine if there is regularity in their spatial distribution, and the orientations of linear troughs and fractures in the region.

Results: In the Arrhenius Region, steep scarps separate areas of higher elevation from areas of lower elevation. Higher elevation areas are characterized by smaller domes, sediment-filled craters, and rampart craters with smooth circumferences in association with smooth-textured plains. On the opposite side of the scarps, lower elevation areas are characterized by larger domes, pristine craters, and pedestal craters with irregular circumferences associated with rough-textured plains, which exhibit fractures and a trough. Based on this observation, we conclude that exhumation has occurred in at least the lower elevation areas. Therefore, Arrhenius is best interpreted as an area of deposition which is now undergoing partial exhumation through aeolian deflation [9].

Table I presents dome measurements and other data from the Arrhenius Region in comparison with several terrestrial volcanic cinder cone fields [10].

SUB-KILOMETER DOMES IN THE ARRHENIUS REGION, MARS: R. Foxx *et al.*

Discussion: When compared with data from Earth, it is clear that the dome morphologies in the Arrhenius region are consistent with a volcanic origin. This interpretation is based on analysis of orientations, diameter relationships, density, presence of a trough and fractures, central pits and dome aspect ratios. Because the average orientations of dome chains and elongate domes are nearly identical it would appear that there is some regional process controlling their formation. We interpret the linear troughs in frame 36 to be fractures related to a nearby graben; both formed in one regional stress regime. The observed alignment and elongation of domes may be controlled by sub-surface fissures that channeled magma up to the surface. Evidence of these fissures exists in the form of linear troughs and graben in frame 36, which exhibit the same alignment as the domes. There are also multiple aligned domes throughout the study area, all in approximately the same orientation as the individual domes and regional fractures. Considered collectively, these lines of evidence are strongly consistent with the argument that the domes are volcanic and that they may have erupted from a regional system of fissures.

Using the mapping results and morphologic data presented two alternative volcanic hypotheses are suggested: cinder cones [2,3,4] and table mountains [2], which are formed in different terrestrial environments. A cinder cone origin implies that the domes were formed when magma erupted onto the surface. The regional stratigraphy would require that dome emplacement would have preceded sediment deposition and subsequent erosion. A table mountain origin implies eruption beneath a cold ice-rich layer. There is direct evidence for a permafrost layer within the sediments (i.e. the rampart craters), which is consistent with a table mountain origin. The sequence of events in this case would be deposition of sediment sheet and permafrost, eruption of magma to form the domes beneath the surface, then exhumation of the sediment sheet to reveal the domes. Because of the resolution of our images, we are unable to determine which of these volcanic processes is most likely to have created the Arrhenius domes. From the evidence we have found, we believe that this area is a result of volcanism, but the exact type is not clear. Further work to constrain the relative timing of the sediment sheet and domes will help discriminate between the two possibilities.

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Acknowledgments: This research was funded as part of a grant from the Keck Geology Consortium during the summer of 1997; we are very thankful for their support. We would also like to thank Dr. Tracy Gregg of the Woods Hole Oceanographic Institute who pointed out the Arrhenius dome field as a research target.

	Our Frames 34 & 36		Ethiopia Rift		Tepic Rift		Transtensional MVB		Canary Islands		Mount Etna	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Number of domes	649		57		100		826		144		188	
Length of elliptical base												
short diameter, km	0.22	1.09	0.10	1.50	0.19	1.70	0.16	1.25	0.05	0.10	0.04	0.70
long diameter, km	0.37	1.89	0.10	1.50	0.22	1.90	0.16	1.90	0.08	1.20	0.80	0.90
Total average basal diameter, km	0.61		0.65		0.80		0.59		0.36		0.29	
% of circular domes	60.4%		26.0%		28.0%		6.0%		8.0%		36.0%	
% of elliptical domes	39.6%		74.0%		72.0%		94.0%		92.0%		64.0%	
Aspect (ellipticity) ratio	0.35	0.99	0.50	1.00	0.34	1.00	0.41	1.00	0.33	1.00	0.33	1.00
Average aspect (ellipticity) ratio	0.63		0.77		0.66		0.75		0.83		0.83	