EFFECT OF ERUPTIVE CONDITIONS ON VOLCANO MORPHOLOGY;

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Lava composition has often been cited as the cause for the various morphologies (shield, stratocone, and dome) of terrestrial effusive volcanic constructs. However, recent studies have discounted the importance of composition and instead suggested that eruptive conditions may control volcano morphology (1,2,3,4,5). The objective of this investigation is to determine the relationships between eruptive conditions (viscosity, erupted volume, eruption rate, and flow dimensions) and terrestrial effusive volcano morphology. Implications of such relationships for extraterrestrial volcanoes are also explored.

In order to evaluate quantitatively the factors that may influence volcano morphology, a literature search was conducted in which viscosity, volume, eruption rate, and flow dimension data were collected for recent eruptions of 60 effusive volcanoes including shields, stratocones, and domes. Results are summarized in Table 1 as a listing of correlation coefficients which describe the degree of correlation between an eruptive parameter and volcano slope on a log-log plot. A coefficient equal to 1.00 indicates a perfect linear relationship.

As demonstrated by the data in Table 1, the highest degree of linear correlation exists between eruptive viscosity (viscosity of lava measured at or near the vent) and volcano slope. This relationship would tend to explain the false observation that composition determines morphology since composition is one of the factors that determines viscosity. Eruption rate and eruptive volume (volume of lava extruded during a typical eruption), which are often cited as important factors in determining volcano morphology, appear to have little effect on slope. Additionally, the lack of correlation between flow length and volcano slope is indicative of the fact that morphologic classifications such as shield, stratocone, and dome describe the shape but not the size of volcanic constructs. While this argument may also be used to explain the poor correlations of eruption rate and eruptive volume with volcano slope, their correlation coefficients with volcano flank width are only 0.45 and 0.28, respectively. Finally, the relationship between the flow thickness/width ratio and volcano slope further substantiates the importance of viscosity in determining volcano slope since the thickness/width ratio is primarily a function of lava viscosity.

The apparent relationship between eruptive viscosity and volcano slope allows for the prediction of extraterrestrial eruptive viscosities based solely on volcano morphology. This was done by inserting the slopes of martian volcanoes [6], lunar domes [6], and venusian volcanoes [7] into the equation for the best fit line between viscosity and slope which is given as

$$y = 2.53 + 2.60\,x$$

where y = log eruptive viscosity and x = volcano slope. The results shown in Table 2 are dependent on several major assumptions: 1) that all volcanoes listed in Table 2 are effusive which may not be the case for some martian paterae [8], 2) that the exposed parts of semi-buried volcanoes accurately represent the geometric shape of the entire volcanic construct, 3) that the extraterrestrial volcanoes have undergone little morphologic modification, and 4) that planetary variables such as gravity, global curvature, etc. are negligible. Given these assumptions, the predicted martian eruptive viscosities are slightly greater than, or equal to, typical Hawaiian eruptive viscosities while those of Venus are slightly less. The predicted eruptive viscosities of lunar domes are also slightly less than Hawaiian shields but still greater than the 10 - 100 poise viscosity of mare lavas [9].

In terms of further work, efforts are currently being made to develop new methods of expressing volcano morphology including a quantitative analysis of the convexity or concavity of volcano slopes. Other possible influences on volcano morphology such as effusion rate peaks, the contribution of pyroclastics, and the importance of summit versus flank eruptions are also being investigated.

Table 1: Correlation Between Mean Eruptive Parameters and Volcano Slope

	Correlation Coefficient	No. Volcanoes
Eruptive Viscosity*	0.89	13
Eruption Rate	0.54	26
Eruptive Volume	0.23	31
Eruption Area	0.77	19
Flow Length	0.60	25
Flow Width	0.53	19
Flow Thickness	0.46	24
Flow Area	0.70	19
Flow Thickness/Width Ratio	0.82	18
Flow Width/Length Ratio	0.14	19
Flow Thickness/Length Ratio	0.75	23

* (lowest reported viscosities measured at or near the vent)

Table 2: Extraterrestrial Eruptive Viscosities

Volcano	Viscosity (poise)
(Mars)	
Olympus Mons	3.5×10^3
Pavonis Mons	5.8×10^3
Ascreaus Mons	1.0×10^4
Arsia Mons	1.5×10^3
Elysium Mons	2.9×10^3
Hecates Tholus	2.0×10^3
Uranius Tholus	2.2×10^4
Ceraunius Tholus	1.8×10^4
Tharsis Tholus	9.3×10^3
Albor Tholus	2.3×10^3
Jovis Tholus	1.5×10^3
Biblis Patera	2.9×10^3
Ulysses Patera	3.9×10^3
Uranius Patera	7.4×10^2
Apollinaris Patera	1.4×10^3
(Moon)	
D crater (name prov)	1.0×10^3
Maraldi B 2NW	8.1×10^2
Cauchy Omega	7.4×10^2
Maraldi B 1SE	1.2×10^3
Rima Aristarchus 8	9.8×10^2
(Venus)	
Theia Mons	8.9×10^2
Rhea Mons	1.0×10^3

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