RELATIVE CHRONOLOGY OF MARTIAN VOLCANOES. R. Landheim[1] and N.G. Barlow[2], [1]Dept. of Geology, Louisiana Tech. University, Ruston, LA 71272, [2]SN21, NASA/Johnson Space Center, Houston, TX 77058.

Impact cratering is one of the major geological processes that has affected the martian surface throughout the planet's history. Crater analysis suggests that two populations of impacting objects have dominated the inner solar system cratering record (1). Heavily cratered surfaces of the Moon, Mercury, and Mars display a crater size-frequency distribution curve which cannot be represented by a single slope distribution function at all crater diameters; this curve is believed to represent the size-frequency distribution of objects dominating the crater production population during the period of heavy bombardment. The heavy bombardment period is believed to have ended approximately 3.8×10^9 years ago (at least in the Earth-Moon vicinity (2)). Terrains formed since the end of heavy bombardment display crater size-frequency distribution functions which do approximate a power law function of incremental slope -3 (cumulative slope of -2) for craters greater than 8 km in diameter. The change in curve shape occurs around a log R value of -2, suggesting that this level represents the cessation of the high bombardment rates at the end of the heavy bombardment period. A relative chronology for Mars has been derived based on the change in shape of the crater size-frequency distribution curves using craters ≥8 km diameter (3). However, volcanic constructs were not generally included in this chronology because of the poor statistics for craters ≥8 km on these features. In this study, we extend the previous work by including craters in the 1.5-8 km diameter range for both volcanic constructs and some geologic units which represented major stages of martian history in the previous chronology. This permits us to incorporate the volcanoes into the aforementioned chronology. Although previous studies have included the volcanoes in both relative and absolute chronologies (4, 5), none of these analyses used the changing shape of the crater size-frequency distribution curves to determine the ages of features relative to the period of heavy bombardment.

We identified and classified 11,486 craters in selected regions of the planet, including the heavily cratered intercrater plains of the southern hemisphere, the rim of the Isidis Basin, Syrtis Major and Lunae Plana, and various plains units in the northern hemisphere. The volcanoes in this study were the medium-sized to large constructs in the Elysium, Tharsis, and Hellas regions. We used the relative crater size-frequency distribution plotting technique in this analysis because the variations in crater distribution curves in which we are interested are more distinctly shown by this technique than by the cumulative technique.

The results of this study are summarized in Table I. This analysis suggests that some medium sized volcanoes in the Tharsis and Elysium regions, previously believed to be young (i.e., post-heavy-bombardment age), actually formed near the end of the heavy bombardment period, as indicated by their multi-sloped distribution curve and position near a log R value of -2. These volcanoes include Albor Tholus, Ulysses Patera, and Hecates Tholus. Crater analysis of Tharsis Tholus, Ceraunius Tholus, Jovis Tholus and Uranius Tholus suggest that these volcanoes formed early, during the heavy bombardment period. In addition, the highland paterae, formerly believed to all have formed within a narrow time period very early in martian history, now show a range in age throughout the heavy bombardment period, including some structures which apparently formed near the end of heavy bombardment. The results of this study, which include consideration of the effects of

obliteration on the crater size-frequency distribution curves, is giving us a more precise estimate of the relative chronology of martian volcanoes.

REFERENCES: (1) Woronow, A., Strom, R. and Gurnis, M. (1982), in *Satellites of Jupiter*, U. Az. Press, 237-276. (2) Wetherill, G.W. (1977), *Proc. Lunar Sci. Conf. 8th*, 1-16. (3) Barlow, N.G. (1988), *Icarus*, **75**, 285-305. (4) Neukum, G. and Wise, D.U. (1976), *Science*, **194**, 1381-1387. (5) Neukum, G. and Hiller, K. (1981), *J. Geophys. Res.*, **86**, 3097-3121.

TABLE I
RELATIVE CHRONOLOGY OF MARTIAN VOLCANOES

Post Heavy Bombardment (Type Area: northern plains)	Younger
Olympus Mons	
Pavonis Mons, Ascraeus Mons, Arsia Mons	
Alba Patera	
Elysium Mons, Biblis Patera	
End of Heavy Bombardment (Type Area: ridged plains)	
Albor Tholus	
Ulysses Patera	
Hecates Tholus, Hadriaca Patera	
Amphitrites Patera	
Heavy Bombardment (Type Area: highland intercrater plains)	
Tyrrhena Patera, Tharsis Tholus, Apollinaris Patera	
Ceraunius Tholus	
Jovis Tholus	
Uranius Tholus	Older