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. The frequency of craters within particular size ranges provides information about the formation ages and obliterative episodes of martian geologic units. The Crater Analysis Techniques Working Group (1) recommended that crater size versus crater frequency data be graphically displayed using either the cumulative or relative plotting techniques. We choose here to use the relative technique because it more clearly displays frequency variations within a particular size range than does the cumulative technique. Two distinct curves result from the crater size-frequency distribution analysis of martian terrain units: lightly cratered regions show a flat curve on the relative plot and heavily cratered regions show a multisloped shape (Fig. 1). The transition between these two curves occurs near a log R value of -2. It is believed that these curves describe the population of impacting objects responsible for the cratering record at a particular period of time. Thus, based on the shapes of the crater size-frequency distribution curves, the impact cratering record of Mars can be divided into two distinct populations. The first population was emplaced during the period of high bombardment rates which existed in the inner solar system prior to about 3.8 x 10^9 years ago--this is the population which displays high crater density and a multi-sloped crater size-frequency distribution curve. The second population, characterized by a lower crater density and a flatter size-frequency distribution curve, has dominated the cratering record since the cessation of the heavy bombardment period (2).

In an earlier analysis, Barlow (3) used the relative plotting technique to revise the martian relative chronology based on craters ≥8 km in diameter. That study determined the relationship of twenty-three generalized geologic units to the period of heavy bombardment, based on the crater densities and shape of the size-frequency distribution curve of superposed craters. However, most martian volcanic constructs (because of their young ages or relatively small sizes) contain too few craters in this size range to make the results statistically reliable--thus crater analysis could not be used to include the volcanoes in the Barlow chronology. Other studies have included the volcanoes in both relative and absolute chronologies (4, 5, 6), but 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.

This study extended the Barlow chronology by measuring small craters on the volcanoes and a number of "standard" terrain units. Inclusion of smaller craters in units previously analyzed by Barlow allowed for a more direct comparison between the size-frequency distribution data for volcanoes and established chronology. We mapped and identified 11,486 craters in the 1.5-8 km diameter range in selected regions of Mars, including portions of the heavily cratered intercrater plains of the southern hemisphere, the rim of the Isidis Basin, Syrtis Major, Lunae Planum, and various plains units in the northern hemisphere. Included in this study were the medium sized to large volcanoes in the Elysium (Elysium Mons, Albor Tholus, and Hecates Tholus), Tharsis (Olympus Mons, Ascraeus Mons, Arsia Mons, Pavonis Mons, Alba Patera, Biblis Patera, Ulysses Patera, Tharsis Tholus, Ceraunius Tholus, Jovis Tholus, and Uranius Tholus), and Hellas (Hadriaca Patera, Amphitrites Patera, and

Tyrrhena Patera) regions. The results of this study, summarized in Table I, give us a more precise estimate of the relative chronology of the martian volcanoes.

Most previous studies have generally determined that the highland patera (Hadriaca, Amphitrites, Tyrrhena, and Apollinaris Paterae) formed during a very brief episode extremely early in martian history, whereas the volcanoes in the Tharsis and Elysium regions are much younger (7). Our analyses suggest that some of the volcanoes in the Elysium and Tharsis regions are not as young (i.e., post-heavy bombardment age) as previously believed. These volcanoes include Albor Tholus, Ulysses Patera, Hecates Tholus, and Tharsis Tholus. Ceraunius Tholus, Jovis Tholus, and Uranius Tholus formed even earlier, during the early part of the heavy bombardment period. The highland patera are still found to be old (i.e., heavy bombardment aged), but are now seen to display a wider range of ages throughout the heavy bombardment period than previously believed.

The results of this study lend further support to the increasing evidence that volcanism has been a dominant geologic force throughout martian history (8). However, we must emphasize that all ages derived in this study are averaged over relatively large areas. Smaller regions within the areas studied are likely older or younger than the average age given here. Nevertheless, this technique reveals important new information about the relative ages of volcanic events on Mars.

Obliteration effects (erosion and/or deposition) manifest themselves in the cratering record as an abrupt decline in the frequency of craters less than a certain size. On the crater size-frequency distribution plots, this effect appears as a steep vertical drop at small crater diameters. Our analysis reveals several examples of likely obliteration episodes, as well as examples of recratering on a surface which underwent an obliteration episode in the past. These effects are factored into our age interpretation of the features studied in this project.

Continuing analysis of small impact phenomena will result in a more detailed understanding of martian geochronology. An extension of this research to other areas of Mars will broaden our understanding of how smaller areas fit into the chronology. It will also allow us to better define the extent and amount of obliteration that has occurred in various regions of the planet. Both of these topics will be of great importance in the scientific planning of future unmanned and manned Mars surface missions.

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MARTIAN VOLCANO CHRONOLOGY: Landheim R. and Barlow N.G.

TABLE I
RELATIVE CHRONOLOGY OF MARTIAN VOLCANOES

Younger

Post Heavy Bombardment (Type Area: Northern Plains)
- 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

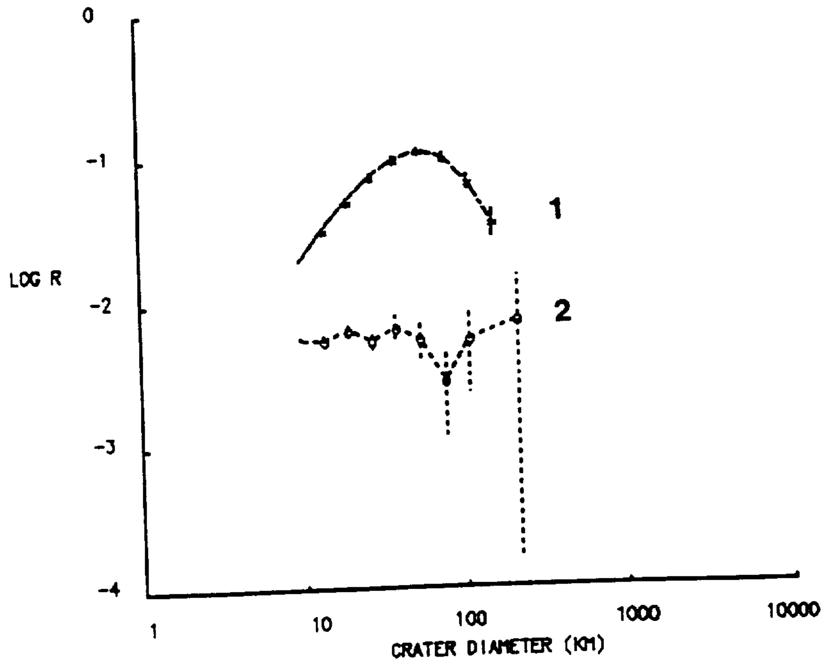

Figure 1: Crater size-frequency distribution plots for martian heavily cratered (1) and lightly cratered (2) regions, as displayed on a Relative Plot. The R value on the vertical axis is a parameter which normalizes the frequency of craters within a particular diameter range to a power law function of -2 slope. Surfaces whose crater size-frequency distribution follows this power law function will appear as a horizontal line on this graph. The difference in shape between the two curves is interpreted as reflective of differences in the size-frequency distribution of the impacting populations.