IMPACT BASINS ON VENUS AND SOME INTERPLANETARY COMPARISONS

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Impact is one of the many processes that have shaped the surface of Venus [1-3]. The largest impact craters, basins, are important features affecting the evolution of the terrestrial planets [4]. Because Venus has an atmosphere, a gravity similar to Earth's, and a surface target with a high geothermal gradient, venusian basins provide an important comparative set of data to test our ideas about basin-forming impacts and their geological effects on the evolution of the crusts of the terrestrial planets.

Spacing of basin rings: The evidence from Venus The spacing of concentric rings has long been thought to be an important constraint on ring origin specifically and the basin-forming process in general [4-7]. Comparative study of multi-ring basins on the Moon, Mercury, and Mars has shown that ring spacing is constant and independent of planet size, target conditions, or position in the Solar System [7]. Rings of the well preserved Orientale basin on the Moon are spaced at a constant factor of $\sqrt{2}$, i.e., the diameter of each ring is $\sqrt{2}$ times the diameter of the ring lying just inside of it [5,6,8]. This relation was subsequently affirmed not only for all other multi-ring basins on the Moon, but also those on other terrestrial planets [7]. Although it was previously held that two-ring basins follow a different spacing law [6], subsequent analysis has shown that the ratio of inner peak ring to basin rim diameter for these features is 1:2 [7]. The $\sqrt{2}$ spacing rule thus accounts for these features as well if the rule is re-stated as "observed rings are spaced at integer powers of $\sqrt{2}$, or $D_n = (\sqrt{2})^N D$, where N is an integer" [7].

The $\sqrt{2}$ spacing should hold for terrestrial impact basins, but the eroded or buried nature of most of these features precludes rigorous statistical analysis [9]. However, Venus is Earth-like in its basic characteristics and displays several basins having nearly pristine surface morphology. Schaber et al. [3] found that for a set of 33 basins and large craters on Venus, multi-ring basins and two-ring basins followed the $\sqrt{2}$ spacing rule while protobasins [7] followed trends similar to those seen for these large craters on the other planets [3]. We independently mapped the rings of 10 venusian basins (Fig. 1) and likewise find that the spacing of basin rings on Venus is well described by the $\sqrt{2}$ factor. Moreover, our analysis confirms that two-ring basins on Venus are well described by the 1:2 ratio, as in [7], interpreted here as a subset of the general $\sqrt{2}$ spacing rule. Protobasins (craters having a peak and peak-ring; [10]) on Venus follow morphometric trends different from either two-ring or multi-ring basins. An example is Yblochkna (48°, 195°), a protobasin that displays both ring and peak (cf. [11]) and has a rim/ring ratio of 2.8, identical to the mean value found for venusian protobasins (2.8 ± 1.0; [3]) and similar to protobasins on other terrestrial planets (3.3 ± 0.6; [7]).

Our analysis supports the concept that basin rings on Venus are spaced according to the same systematics as basin rings on the other planets [3,7]. Although scatter is seen in the statistical sample [11], as it is for all terrestrial planet basins [7], we are impressed more with the similarity than the diversity of the spacing of venusian basin rings. Such regularity imposes stringent constraints on models of ring genesis [4,7]. Models of ring formation that call upon special conditions of the impact target to control ring formation (such as crustal layering [12] or lithospheric thickness [13]) are not supported by a constant spacing of rings on many bodies of widely varying environments and surface conditions.

Venusian multi-ring basins: Pristine analogs to degraded terrestrial structures Active geological processes on Earth rapidly modify and remove the original surface expression of impact craters, but in many cases, such processes provide invaluable access to crater substructure. Reconstruction of the original crater morphology via comparison with pristine craters on the smaller terrestrial planets is hindered by incomplete knowledge of how such variables as gravity, target properties, and atmosphere affect the cratering process and resulting landform. Venus is earth-like in terms of gravity, atmosphere, and lithospheric thickness. Consequently, the craters and basins of Venus, being both abundant and having pristine morphology, are potentially a Rosetta Stone for deciphering the cratering process on the Earth [14].

The largest impact basins recognized on the Earth are the Sudbury basin, Vredefort Dome, and Chicxulub basin. Sudbury and Vredefort are heavily modified by erosion and tectonic deformation; Chicxulub is virtually pristine, but is buried beneath a 1 km thickness of carbonates. Sudbury, in particular, provides excellent exposure of the interior and vertical structure of a large terrestrial impact basin.

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Moreover, the recent concept that the igneous complex of Sudbury is a differentiated impact melt sheet [15] can be tested through comparative studies of basins of comparable size on Venus. Chicxulub can provide complementary information on and insight into unmodified terrestrial basin structure and morphology. Recent analysis of gravity data over Chicxulub structure suggests that it is a 200 km diameter multi-ring basin [16]. The spacing of the Chicxulub basin rings expressed in the *gravity* data conform to the √2 rule derived solely from the study of the *topographic* rings of planetary basins on Venus and elsewhere (Figure 1; [7]). The best planetary analog to both Sudbury and Chicxulub is the 170 km diameter multi-ring basin Isabella on Venus. We are currently using the complementary sources of information provided by Sudbury, Chicxulub, and Isabella to reconstruct a more complete picture of the formation of multi-ring basins on the terrestrial planets.

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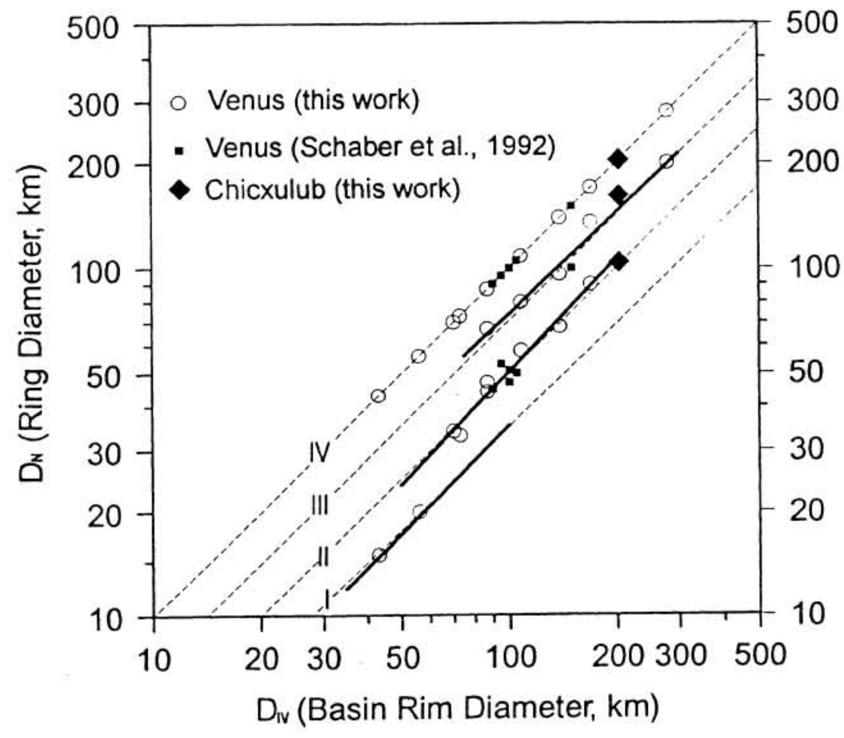

Figure 1. Plot of observed rings (D_N: D_{IV}, D_{III}, D_{II}) against main basin rim (D_{IV}), after convention used by [7], for 16 basins and protobasins on Venus. Open circles our data, solid squares from [3], and solid diamonds are rings observed in gravity data for terrestrial Chicxulub crater [16]. Top line is ring IV (basin rim) plotted against itself; linear least-squares fits (solid black lines) and model (√2) values (dotted lines) shown for intermediate (III), peak (II), and innermost rings (I), after [7].