CRATERING ON VENUS: MODELS AND OBSERVATIONS

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Venus has the densest atmosphere of the terrestrial planets. High-resolution radar images demonstrate the important influence of this atmosphere on would-be impactors. Small multiple and slightly larger irregular craters ($\sim$1.5–15 km in diameter) are clear evidence for deceleration and breakup of impactors $\lesssim$1 km in diameter. The crater size-frequency distribution observed on Venus is distinctive. It is deficient in craters as large as $\sim$30-km diameter and probably larger and lacks smaller craters entirely. As craters on Venus are nearly all well preserved, the lack of small craters is logically caused by the failure of small bodies to strike the surface. This dearth is qualitatively and quantitatively explained here by a model of atmospheric intervention. The atmospheric screen is very effective, but careful attention to atmospheric deceleration and impactor flattening is necessary to constrain reliably the crater retention age of the surface. Our nominal models, which incorporate the flattening seen in most of the best-resolved numerical simulations, yield ages of $\sim$750 Myr. The crater size-frequency distribution is consistent with a constant atmospheric pressure over the period of observed crater accumulation. Objects that fail to reach the surface often effectively explode. Strong shock waves during cratering or from such airbursts can shatter and fragment surface rock and create powerful, high-speed surface winds that may do the same. The results are dark and bright halos and splotches, characteristic radar-albedo features that may form, Tunguska-like, even in the absence of a central crater. More than 50 fresh impact craters are associated with west-opening, radar-dark "parabolas." These are most plausibly explained as deposits of small particles that were initially ejected through the atmosphere with the expanding vapor plume above the impact site; the particles then coasted ballistically, re-entered the atmosphere, and drifted westward under the influence of the steady, high-altitude zonal winds before being deposited. Craters on Venus are morphologically complex, i.e., modified by gravitatively driven restoring forces, yet they are deep, considering Venus' gravity, compared with similar craters on the Moon, Mercury, and Mars. This difference is more apparent than real, and can be explained by a modestly greater transient strength for cratered Venusian

crust and/or Venusian craters being so flat that mechanical equilibrium is determined by their apparent, or below-ground-plane, depths. The abundance of impact melt in Venusian crater ejecta should be much higher than on the Moon, with the proportion increasing with increasing crater size and impact angle (to the zenith). This is probably one of the major causes of the extensive ejecta flows seen on Venus.