VENUSIAN IMPACT CRATERS: EFFECTS OF DIFFERENTIAL SCALING; R.A.F. Grieve* and M.J. Cintala.

"Impact craters on Venus larger than about 15 km in diameter are similar to those on other planetary bodies; they are typically circular and exhibit some or all of the features typical of complex craters." While the essence of this statement is correct, it serves to mask the differences between venusian impact craters and those on other silicate planetary bodies. Potentially important differences exist between complex craters because of variations in the physical conditions of impact on different planets. For example, lunar and terrestrial complex craters are not identical in depth, width of terracing, etc. Prior to the availability of radar-image data of the venusian surface, it was argued that venusian craters would be more like terrestrial than lunar craters in appearance. Magellan data now provide a basis for testing predictions of theoretical studies and models.

Interactions of an impacting body with the dense venusian atmosphere have been predicted and result in a number of observed phenomena, ranging from crater clusters due to projectile breakup to various effects on the exterior ejecta and the surrounding planetary surface. Here, however, we concentrate on effects related to cratering mechanics and the nature of impact melting as dictated by the Earth-like gravity (8.9 m s⁻²), high surface temperature (740 K), lack of water, and relatively high mean impact-velocity that characterize Venus. To provide predictions, we use the thermodynamic calculations and a modified version of scaling relations employed previously. We also assume a diabase target with the ambient physical conditions noted above to approximate the venusian surface; venusian transient cavity geometries are also assumed to be similar to those on the Earth.

Morphometry: The volume of impact melt produced in a given impact event is a function of impact velocity and temperature of the target rocks, with the former generally dominating the latter in its effect (Fig. 1). Using a typical asteroidal source of impactors, the volume of melt produced at Venus would be about 5.7 and 1.1 times, respectively, those produced in lunar and terrestrial impact events that would yield equivalent-sized transient cavities (Fig. 2). When scaled to equivalent final rim-crest diameters (Dₛ), this translates to about 3 and 1.25 times the volumes produced in lunar and terrestrial events, respectively. The importance of these differences in terms of crater morphology is stressed by the observation that impact melt constitutes the bulk of crater fill in terrestrial complex craters formed in crystalline rock. Altimetry from Venera 15/16 indicates that apparent depths of about 0.7 km are typical for 100-km craters on Venus, although this is considered to be a minimum. More recent analyses of Magellan altimetry give depths closer to 1 km. These values are considerably lower than those determined by radar layover on Magellan images, which give an equivalent depth of about 2.5 km. According to our model calculations, the volume of melt at a 100 km venusian crater will be more than 3600 km³. Assuming a true depth (i.e., the depth to the base of any infilling material) of 1.6 km from our model calculations, the volume of melt at a 100-km venusian crater would be about 5.7 times the volume produced in a terrestrial crater of the same size. This is a maximum value for this example, since the volume occupied by uplifted central structures has not been taken into account. Nevertheless, it is of the same order given by the Venera and Magellan altimetry data, and supports the earlier suggestion that venusian complex craters should have morphometries more akin to their terrestrial than to their lunar equivalents.

Cleopatra (Dₛ=100 km) is unusually deep (2.5 km) for a venusian crater. It has, however, an associated plains-forming unit, which has been suggested to be "escaped" impact melt or impact-induced volcanism. Given the above discussion of melt and associated thicknesses of impact melt sheets, we favor the draining of interior impact melt as the most likely explanation both for the depth of Cleopatra and for the formation of the associated plains unit.

Exterior Morphology: Another observation noted at some large complex craters on Venus is the outflow of apparently highly fluid material from the exterior ejecta. It has been suggested that this material is either very fine ejecta or impact melt from within the ejecta. The relatively high volumes of melt in venusian craters favor the latter suggestion. Ejected melt will be effectively strengthless and, as such, will break up into a fine spray as it encounters the surrounding atmosphere. Drag forces will be extreme, and most of the melt ejected should be deposited very near the crater. In addition, the post-impact temperature and viscosity of venusian impact melts will be higher and lower, respectively, than their lunar or terrestrial equivalents. It is the incorporation and digestion of (usually cold) clastic debris that is the driving force for the initial cooling of impact-melt sheets. In the case of Venus, however, this clastic debris is relatively hot, by virtue of the high ambient temperature. On the basis of model calculations for Manicouagan, venusian impact melts will cool initially on time scales of 10 s by clast incorporation, but they will equilibrate at a temperature some 400 K higher. Thus, the viscosity of the equilibrated melt will be lower by two orders of magnitude compared to a lunar impact melt of basaltic composition. Venusian impact melts will take
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longer to cool and crystallize. Not only will they have initially higher equilibrated temperatures, but they will also be in contact with relatively hot country rock and atmosphere, and the increased atmospheric opacity resulting from fine ejecta suspended in the thick atmosphere may discourage rapid radiative heat loss. While atmospheric convection might be effective in removing heat from the area, its effectiveness will be diminished somewhat by the reduced temperature contrast between the atmosphere and the impact site. Therefore, a greater potential for flow of impact melt is expected on Venus in response to local crater readjustments for time periods longer after flow would have ceased in lunar and terrestrial equivalents.

**Interior Morphology:** Only a 2% increase in crater fill (-350 km$^3$) would be sufficient to bury the hummocks and general crater flow roughness in Copernicus on the Moon. Given that melt volumes in venusian impact events are 200% greater than in their lunar equivalents under the impact-velocity distribution assumed above, it is probable that apparent crater floors will be considerably smoother on Venus. The relative increase in melt volumes will also result in more cylindrical cross-sections, which appears to be the case. Finally, we have noted previously that the intersection of melting with the base of the transient cavity requires that the target rocks at the base have little or no strength. Thus, uplift during the modification stage cannot result in a central topographic peak, although interior rings might form.

This intersection occurs at rim-crest diameters of 60-80 km for venusian impact conditions, which agrees well with Magellan and Venera data that indicate central peaks disappear in venusian craters at about 90 km.

**References:**