Radar Scattering Mechanisms within the *Meteor Crater* Ejecta Blanket: Geologic Implications and Relevance to Venus: *J. B. Garvin*, B. A. Campbell#, S. H. Zisk#, G. G. Schaber@*, and *C. Evans%*: *Geodynamics Branch, NASA/GSFC, Code 621, Greenbelt, MD 20771; #Planetary Geosciences Div., Hawaii Instit. of Geophysics, U. Hawaii, Honolulu, HI 96822; @Branch for Astrogeology, U. S. Geological Survey, Flagstaff, AZ, 86001; %Univ. Maryland Dept. of Astronomy and NASA/GSFC, Greenbelt, MD 20771.

Simple impact craters are known to occur on all of the terrestrial planets and the morphologic expression of their ejecta blankets is a reliable indicator of their relative ages on the Moon, Mars, Mercury, and most recently for Venus [e.g., 1,2]. In addition, the geology of impact crater ejecta blankets has been shown to reveal details of the physics of the ejecta emplacement process as manifested by distintive facies and morphologies (e.g. hummocks) [1-3]. The Magellan S-band SAR dataset to be acquired for Venus is expected to provide 120-360 m resolution images of hundreds to thousands of craterforms, many of which are likely to be of hypervelocity impact origin. It will be crucial for the interpretation of the geology of Venus to develop a reliable means of distinguishing smaller impact landforms from volcanic collapse and explosion craters, and further to use the observed SAR characteristics of *crater ejecta blankets* (CEB) as a means of relative age estimation. With these concepts in mind, we have initiated a study of the quantitative SAR textural characteristics of the ejecta blanket preserved at *Meteor Crater*, Arizona, the well-studied 1.2 km diameter simple crater that formed ~49,000 years ago from the impact of an octahedrite bolide [3,4]. While Meteor Crater was formed as the result of an impact into wind and water-lain sediments [3] and has undergone recognizable water and wind-related erosion [3-5], it nonetheless represents the only well-studied simple impact crater on Earth with a reasonably preserved CEB. Recent field geomorphic investigations of the Meteor Crater CEB by Grant and Schultz [6] have challenged the previous work by Roddy and colleagues [4,5] that suggested about 20% of the ejecta has been removed, and the new, albeit controversial, evidence indicates that the ejecta is still in a pristine state [6]. Therefore, we are also interested in exploring whether the scattering behavior of the CEB can provide an independent perspective on its preservation state and style of erosion. Finally, we have used airborne laser altimeter profiles of the microtopography of the Meteor Crater CEB [7] to further quantify the sub-radar pixel scale topographic slopes and RMS height variations for comparisons with the scattering mechanisms computed from SAR polarimetry. This report summarizes a preliminary assessment of the L-band radar scattering mechanisms within the Meteor Crater CEB as derived from a NASA/JPL DC-8 SAR Polarimetry dataset acquired in 1988, and compares the dominant scattering behavior with microtopographic data (laser altimeter profiles and 1:10,000 scale topographic maps).

Campbell and colleagues [8] have demonstrated that polarimetric SAR backscatter data from volcanic lava surfaces can be reasonably represented by a model in which the entire coherent echo from the surface is separated into quasi-specular (QS), quasi-dihedral (DI), and Bragg-resonant (BR) components. Details of this approach are summarized in [9], and a general description of the analysis of multipolarization SAR data in Stokes matrix format is given by van Zyl and colleagues [9-11], and will not be reviewed here. Campbell and colleagues [8] have convincingly shown that this radar model produces quantitative information about the relative surface roughness of lava flows, and that it should be extensible to the Meteor Crater if the CEB can be modelled as dielectrically homogeneous. Furthermore, they have demonstrated that RMS height variations and other topographic parameters can be deduced from the types of scattering components. We have used terrain properties computed from meter-resolution laser altimeter profiles [7] to quantify the Meteor Crater CEB as a function of range (from the rim crest) and azimuth. For a 500 m long section of the eastern CEB, the RMS height variations are approximated by a power law of the form: **RMS = 0.032 (delta x)^1.06** in meters, where delta x is the spatial scale over which the RMS height variation is desired. In a similar manner, the scale-dependent local topographic slope can be described by a power law of the form: **Slope = 6.8 (delta x)^-0.106** in degrees. Thus, the 10 cm spatial-scale RMS height variations (on the average) for the near-rim ejecta range from 0.14 to 0.47 cm as a function of azimuth around the crater, and the 1 m scale RMS variations range from 2 to 4.3 cm. At the scale of a 10 m SAR polarimeter pixel, the RMS height variations range from 23 to 49 cm, with the eastern and northeastern ejecta the roughest (40-49 cm RMS per 10 m). Local slopes at 10 cm scales vary from 4 to 8 degrees. Even at 10 m spatial scales, local slopes range from 3.4 to 7.2 degrees as a function of azimuth around the crater. These values for the Meteor Crater CEB are dramatically different by factors of up to 10 from similar statistics derived from microtopographic statistics for lava flows such as SP (AZ). The blocky SP lava flow averages over 18 cm of RMS height variation at 1 m scales, and 71 cm of RMS relief at 10 m (DC-8 SAR pixel) scales. Local slopes at radar pixel scale average 11 degrees, while those at 1 m scale lengths are typically 36 degrees. Therefore, our prediction is that the Meteor Crater CEB is much more benign at radar wavelengths than blocky or a'a lava flows.

We have applied the model described in [8] to the DC-8 SAR polarimetry (at L-band only) of Meteor Crater and its CEB (out to 5 crater radii), after having corrected these data for HH and VV phase errors and cross-talk using algorithms developed by J. van Zyl [11]. In order to evaluate the effect of dielectric homogeneity of the surface layer in the vicinity of the crater, we have computed model solutions for E'=4, 6, and 8; for reference, only very dense, competent rocks have dielectric permittivities as high as E'=8, and there is no obvious physical evidence for high dielectric phases *at the surface of the CEB* . A simple color (RGB) composite image involving the QS, BR, and unpolarized (UN) components of the radar model reveals the dominant textural variations of the CEB. The DI component is extremely subdued in the CEB, perhaps due to a general absence of natural "corner reflectors" except at the rim. We examined the differences between the composite BR, QS, and UN images as a function of dielectric permittivity E', and in correlation with topography and geology. The E'=8 model is most sensitive to local variations in surface texture, and best depicts the spatial variability and asymmetry of the ejecta [3-5]. There is a sense of bilateral symmetry to the ejecta as revealed in the scattering mechanism images, about an axis oriented E-W. This is not consistent with the theory of a directed impact from the SE [5], but the effect may be due to an erosional imprint or radar look azimuth biasing. The expression of the CEB in the composite image (BR,QS,UN) is strongest to the NE and South/SE, and is most subdued to the West. This is consistent with the results of a radial topographic analysis of the CEB [7]. A significant component of the scattering in the CEB is represented by the unpolarized (UN) echo, although most of terrain appears to behave as QS facets. The E'=8 model suggests that the "roughest" areas of the ejecta have a higher dielectric permittivity, which is consistent with their occurrence as isolated ridges of rock outcrops within the more friable (eolian lag covered) ejecta deposit. An apparenlty random spatial distribution of isolated, lower dielectric regions exists around the crater, and these areas are not correlated with the limits of the CEB.

Our preliminary examination of the radar scattering characteristics within a partially preserved impact crater ejecta blanket suggest a few cautions. First, the Meteor Crater ejecta blanket may not be the ideal analogue for such terrain types on planets such as Venus or the Moon. This is because of the generally benign nature of the Meteor Crater CEB, at least relative to lava and block field surfaces. While the scattering behavior of the CEB is distinct from the surrounding terrain, it is not representative of a blocky surface unit, as is suggested from existing radar observations of probable venusian impact craters [2]. It is possible that a partially fluidized mode of late-stage ejecta emplacement at Meteor Crater has subdued the expression of the ejecta block field within one crater radius from the rim. In spite of the possible uniqueness of the preserved CEB at Meteor Crater, the suggestion that ejecta blankets may have dielectric permittivities that are larger than their surroundings warrants further examination in light of enhanced radar reflectivities observed around probable venusian impact craters. {This work was partially supported by NASA/GSFC DDF 88-04 and RTOP 677-43-24}.

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