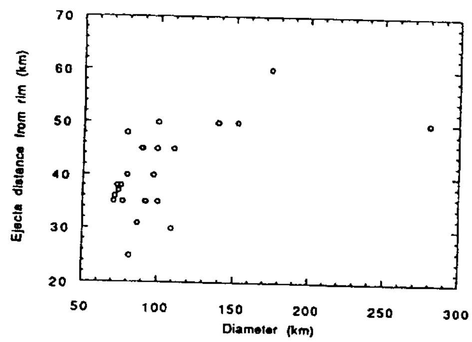

Fig. 3. Ejecta distance from the crater rim vs. diameter.

phenomenon needs additional study to investigate the effect of the atmospheric scale height on ejecta deposition.

The Inner Ring Position: A number of venusian impact craters have asymmetric BED blankets, which may result from the obliqueness of the impact. The general features of this asymmetry have been investigated experimentally for small-scale impacts [9]. At least two venusian craters (Cohran: D = 100 km, RDR = 0.5; Marie Celeste: D = 99 km, RDR = 0.62) have a definite offset of the inner ring in respect to the outer crater ring. If this offset is a consequence of an oblique impact, then we would expect the inner ring to be shifted to the deepest part of the transient cavity, which should be on the uprange side. In fact, Cohran and Marie Celeste have their inner ring offset downrange rather than uprange. Although these two craters suggest that we cannot accurately predict the formation of the multiring structures, we still have a poor understanding of cratering mechanics at this time so we need to investigate this process further. This investigation of the largest craters on Venus is therefore providing new constraints both for cratering mechanics and for the regional geologic study of Venus.

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N93-14327

VENUSIAN EXTENDED EJECTA DEPOSITS AS TIME-STRATIGRAPHIC MARKERS. Noam R. Izenberg, McDonnell Center for Space Sciences, Washington University, St. Louis MO 63130, USA.

In contrast to the Moon, Mars, and Mercury, where millions of impact craters cover or influence nearly all surface terrains, on Venus there are only about 850 craters. For the Moon, Mars, and Mercury, relative densities of craters on different geologic surfaces provide clues regarding relative age relationships for surface units, both on regional and local scales. For Venus, the population of craters is well dispersed, and based on extensive statistical analysis of the spatial distribution of impact craters, Magellan investigators [1] find that the hypothesis that craters are randomly distributed cannot be rejected. Relative age dating using crater statistics alone is therefore not possible for Venus. However, in the absence of actual rock samples, the venusian crater population is the only tool available for determining a general planetary timescale. An average surface age of approximately 500 Ma is indicated by the total abundance of impact craters, using the assumption that all craters produced over that time have been retained and observed by the Magellan spacecraft [2]. One of the first-order questions regarding Venus presently is whether areas of the planet are clearly older or younger than this statistically determined average age.

On the regional scale, the question of relative age can be approached by examining the crater population and its associations with large-scale geologic terrains. Upon construction and examination of a crater distribution plot, craters appear randomly distributed across the planet. A density plot in which the total crater population has been binned in 20° radius circles every 10° of latitude and longitude to maximize the visibility of regional trends in the concentrations of craters has also been constructed. Some areas show regions with one-third to one-fourth the average planetary crater density, while others represent regions with up to twice the planetary mean. If these low- and high-density areas correlate with the regional geology of the planet, then these regions have ages younger and older than the planetary mean respectively.

The work of [3] and [4] has shown that correlations between crater concentrations and geology do exist. For example, the Beta-Atla-Themis region, shown to have the highest density of volcanic structures on the planet [5], has a low density of impact craters. Likewise, south central Aphrodite Terra, including Artemis Chasma (a large coronae feature on the southern edge of Aphrodite), also has a low crater density. These two areas probably represent broad regions younger than the planetary average age.

On the local scale, both the paucity and distribution of impact craters precludes them as relative age indicators. Relative ages must be established using other means, such as through interpretation of stratigraphic relationships between surface units. Extended ejecta deposits, which cover many times the surface area of their parent craters, are units that provide areally extensive time-stratigraphic markers for their respective localities. Superposition relationships between these deposits, volcanic materials, and tectonic zones would establish relative timing for the deposition of the units involved.

Use of impact crater ejecta as time-stratigraphic markers was established during lunar geologic mapping efforts [6,7]. The basic premise is that the deposition of impact ejecta, either by itself or mixed with impact-excavated material, is superimposed on a surface. The deposit becomes an observable, mappable unit produced in a single instant in geologic time. Up to two-thirds of Venus craters exhibit extended ejecta deposits. Most deposits have low specific radar cross sections, appearing dark on Magellan images relative to surrounding units. Some deposits have specific cross sections higher than the local mean, and some have a number of high and low specific cross-section components. The deposits range in characteristics from extensive parabolic features to halolike zones only a few crater diameters across. Parabolic features are interpreted to be due to interactions of ejecta with strong east-to-west zonal winds [8,9,10]. They extend up to 20 crater radii from the impact site. Ejecta halos, 3 to 10 times the parent crater radius in areal extent, are interpreted to be due to a combination of shock-induced crushing of preexisting material and accumulation of ejecta from the relevant impact crater [1,2,11].

The areal extent of a given extended deposit is significantly greater than that of its parent crater. The largest extended ejecta deposits are associated with craters Greenaway and Stanton and cover about 100 times the area of each crater, 2.6 and 3.4 million km^2, or 0.6% and 0.8% of the total surface area of Venus respectively. Assuming that extended ejecta is contemporaneous with the parent crater as a given, it follows logically that extended ejecta deposits are local time-stratigraphic markers. Such extended units will not improve temporal resolution (i.e., they will not give a better constraint on absolute time, since they are present around a subset of the already small, spread-out crater population). However, the extended deposits will improve the spatial domain significantly, as the deposits cover up to millions of square kilometers in a single geologic instant, allowing for determination of relative time progressions in many localities.

A reconnaissance survey of 336 craters (about 40% of the total population) was conducted. About half the craters examined were located in and around the Beta-Atla-Themis region, and half were spread over the western hemisphere of the planet. The survey was conducted using primarily C1-MIDR images. The preliminary survey shows (1) Of the 336 craters, 223 were found to have extended ejecta deposits. This proportion is higher than that found in other Venus crater databases by up to a factor of 2 [12]. (2) 53% of all extended ejecta craters were unambiguously superimposed on all volcanic and tectonic units. Figure 1 shows a representative example of this group. Crater Annia Faustina's associated parabolic ejecta deposit is clearly superimposed on volcanic flows coming from Gula Mons to the west (Gula is not shown). Parabola material from Faustina has covered the lava flows, smoothing the surface and reducing its specific backscatter cross section. The stratigraphy implies that the parabola material is the youngest observable unit in the region. (3) 12% of extended ejecta deposits are superimposed by volcanic materials. Figure 2 shows a typical example. Crater Hwangcini has extended ejecta that has been covered by volcanic flows from a dome field to the northwest, implying that the volcanic units were emplaced subsequent to the ejecta deposit and are the youngest units in the locality. (4) It is difficult to determine the stratigraphic relationships of the remaining extended ejecta deposits in SAR at C1-MIDR resolution. Examination of higher resolution images and application of the other Magellan datasets in a systematic manner should resolve most of the ambiguous cases.

Fig. 1. Crater Annia Faustina, located east of Gula Mons. The crater is 22 km across, and the parabola is 6630 km long and and 720 km across. Parabola material from Faustina clearly darkens lava flows from Gula Mons where it appears that centimeters to decimeters of covering ejecta material reduces the radar wavelength scale roughness of the surface.

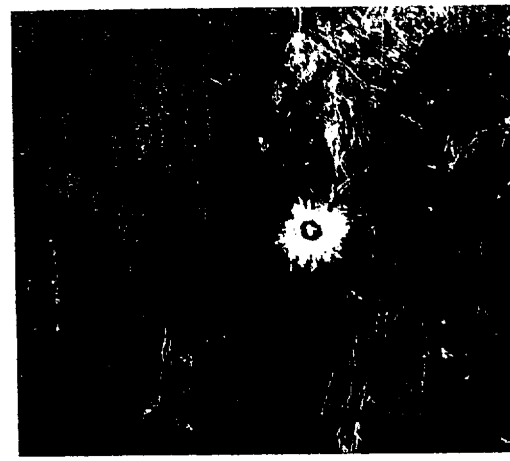

Fig. 2. Crater Hwangcini, 31 km in diameter with a low cross-section halo of about 230 km diameter that has been embayed to the west by flows associated with the dome field there. The crater is located northwest of Thetis Regio.

Results from the preliminary survey indicate that extended ejecta deposits are effective time-stratigraphic markers for their localities. If stratigraphic relationships between the deposits and surrounding units are studied on a case-by-case basis over the whole planet, they should provide useful constraints on Venus history and development of the surface through time. The continuation of this research will expand the study to include the entire crater population and the Magellan emissivity, altimetry, reflectivity, and rms slope datasets.

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LONG-TERM VARIATIONS IN ABUNDANCE AND DISTRIBUTION OF SULFURIC ACID VAPOR IN THE VENUS ATMOSPHERE INFERRED FROM PIONEER VENUS AND MAGELLAN RADIO OCCULTATION STUDIES. J. M. Jenkins[1] and P. G. Steffes[2], [1]SETI Institute, NASA Ames Research Center, Moffett Field CA 94035, USA, [2]Georgia Institute of Technology, Atlanta GA 30332, USA.

Radio occultation experiments have been used to study various properties of planetary atmospheres, including pressure and temperature profiles, and the abundance profiles of absorbing constitu-