VENUS: FRACTURED CRATERS REVISITED, AND THE EVIDENCE FOR MINIMAL GEOLOGIC ACTIVITY OVER THE PAST 300 M.Y.; **G.G. Schaber**, U.S. Geological Survey, Flagstaff AZ, R.G. Strom, U. of Arizona, Tucson AZ, and D.J. Chadwick, U.S. Geological Survey, Flagstaff AZ

Fractured Craters-A total of 932 impact craters have been identified on 98% of the surface of Venus. This impact record constitutes a virtually complete survey of the Magellan data as well as the Venus cratering record. A recent reassessment of the modification classes of these craters using the Magellan image dataset has revealed that a remarkable 84% of all craters have pristine morphologies [1]. Only 12% of the craters are now classified as clearly fractured (8.5% slightly fractured; 3.5% heavily fractured); only 3.5% of the craters are embayed by volcanic deposits. It is no surprise, considering the higher elevation of the major fracture belts, that we find that the mean elevation of the heavily fractured craters is highest (6052.86±2.03 km), followed by elevation of slightly fractured craters (6052.19±1.50 km), lava-embayed craters (6052.17±0.83 km), and pristine craters (6051.74±0.83 km). These mean elevations for different crater classes are in general agreement with [2]. The percentage of craters interpreted as fractured has been reduced by half from our original estimate of 33% [3]. According to our new methodology for assessing modification, craters are classified as fractured only if one or more fractures are clearly observed to transect the crater rim and floor. Because crater floors on Venus are commonly flat, smooth, and therefore radar-image dark, they provide an optimal contrast in radar backscatter to crosscutting, radar-bright fractures. Upon examination of the entire Magellan image dataset, we found, for example, that many lineaments earlier recognized within the ejecta of craters on highly fractured terrains do not actually cross the floor deposits and are, in fact, pre-existing structures only thinly blanketed by ejecta.

Using standard statistical methods, we have confirmed that the distribution of impact craters on Venus is consistent with a completely random one (including stochastic variations), both spatially (as originally shown by [4]) and hypsometrically (i.e., with regard to elevation) [1] (See poster talk [5].) These results are not in agreement, however, with a report of possible ancient terrains on Venus [6], or with the suggestion that the craters are distinctly nonrandom with elevation [2]. As a result of the paucity of impact craters on Venus and their completely random distribution, it is not possible to determine surface ages, even on a regional basis. Nevertheless, three separate regions (covering 25±10% of Venus' surface) with distinct surface ages have been proposed by [7].

We find that about 9% (13 of 147) of all craters ≥35 km in diameter and 11% (47 of 428) of all craters ≥16 km in diameter lie on tesserae. These percentages agree very well with the percentage of the planet's surface (10%-11%) estimated to be occupied by tesserae [8]. Given the spatially and hypsometrically random distribution of impact craters, these results for the larger craters are interpreted to indicate that the average surface age of the tesserae is statistically the same as that for the entire planet (about 300 m.y.). The results do not support the older average age (900+430-330 m.y.) for tesserae suggested by [8], based on their independent tesserae crater counts. We agree with [8], however, that there is a deficiency (of about half) of impact craters <16 km in diameter on tesserae, and that most of these missing craters may be unrecognized on the rough terrain.

We have shown that a global resurfacing event ending 300±200 m.y. ago best accounts for (i) the random spatial and hypsometric distribution of the impact craters, (ii) the low crater density (1 per 500,000 km^2), and (iii) the paucity of impact-related features (craters, haloes and splotches) that have been embayed by volcanic lava flows [1,3]. In the global resurfacing model, extreme tectonic and volcanic activity prior to about 300 m.y. ago acted together to obliterate the pre-existing record of early heavy bombardment and later light bombardment. The extensive lowland plains on Venus were resurfaced dominantly by volcanism, while at the same time the less abundant, higher tesserae were resurfaced dominantly by tectonism [1,3]. There is evidence from studies of tectonic deformation within some tesselated uplands that global-scale resurfacing may have been episodic throughout Venus' history [9], as earlier suggested by some thermal evolution models [10].

Minimal Geologic Activity Over the Past 300 m.y. The record of geologic activity on Venus over the past 300 m.y. is well preserved. It suggests much lower levels of tectonism and especially volcanism than the levels of earlier periods, which completely erased the preexisting cratering record. Recent modification of the Venusian surface has been largely the result of simple fracturing (with limited extension) and regional volcanism on such a low level that the cratering record has been left virtually intact.

In general, the most recent geologic activity postdating the proposed global event has occurred along broad fracture belts that criss-cross the middle latitudes of the planet and were first described from Pioneer Venus altimetry [11,12]. Three broad tectonic "disruption zones" were named the Aphrodite-Beta, Themis-Atla, and Phoebe-Atla zones and attributed at that time to limited extension [12]. The Magellan data support this interpretation and show the disruption zones to be complex, anastamosing belts of closely spaced fractures, grabens, coronae, and volcanic eruption centers. Where the three disruption zones broadly intersect in the vicinity of Maat and Ozza Montes in Atla Regio and near Theia Mons in Beta Regio, there is evidence of ongoing shield volcanism. High-emissivity volcanic peaks at high elevations, combined with spatially related, low-emissivity, volcanic domes on the plains, have been interpreted to indicate recent volcanic activity [13]. Sites of such activity are in the Beta-Atla-Themis (BAT) region, which has been described as having the highest density of volcanic landforms on Venus [14]. Three of the larger shield volcanoes (Sapas, Maat, and Ozza Montes), all in Atla Regio, are grouped together and are closely associated with five embayed craters (the densest concentration of such craters on the planet); Maat Mons is thought to have been the most recently active [13]. Thus, the general region at the intersection of the Themis-Atla and Aphrodite-Beta tectonic belts may have been the locus of the most recent volcanic activity on Venus. Also, this region was likely the location of a significant fraction of the estimated 20 or so craters actually destroyed since the last global resurfacing event. The 33% of Venus' surface bordered by lat ±30°, long 60°-300° E. contains twice as many heavily fractured impact craters as the planetary average and 1.4 times more lava-embayed craters [1,3]. This region includes most of the major tectonic belts in the equatorial region. Given that the craters are statistically random both spatially and hypsometrically, this concentration of heavily fractured craters and embayed craters is statistically significant and indicative of a continuing low level of limited extension and volcanic activity in this region over the past 300 m.y. For tesserae craters ≥16 km in diameter, 15% (7 of 47) are slightly fractured and 13% (6 of 47) are heavily fractured; thus, the tesserae areas appear to have been slightly more tectonically active than the planetary average over the past 300 m.y. We must keep in mind that the modified craters on Venus are simply fractured and/or embayed, and very few have been subjected to complete tectonic disruption, complete burial, and subsequent removal from the surface as was the case during the latest global resurfacing event. Nothing other than global resurfacing, followed by the present level and style of geologic activity, could have produced the observed cratering record.

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