DEFORMATION OF CRATERS ON TESSERA TERRAIN, VENUS; Martha S. Gilmore[1], Mikhail I. Ivanov[2], James W. Head, III[1], Alexander T. Basilevsky[1,2], [1]Department of Geological Sciences, Box 1846, Brown University, Providence, RI 02912, Martha_Gilmore@brown.edu [2]Vernadsky Institute of Geochemistry and Analytical Chemistry, Russian Academy of Sciences, Moscow V-334, Russia, ABasilevsky@glas.apc.org

The Venus cratering record has been shown to have a distribution that is indistinguishable from one that is spatially random [1], leading to the interpretation that the planet underwent a catastrophic resurfacing event 300 (+300/-110) Ma ago [2]. Although >80% of the surface is composed of volcanic plains, this average age applies to all terrains, including the highly deformed tessera terrain which has been shown in the vast majority of cases to be stratigraphically older than the plains. Using high resolution Magellan data, we have compiled an independent list of tessera craters on Venus, extending to smaller crater sizes the work done by Ivanov and Basilevsky [3]. We then examined each of the deformed craters to determine whether the deformation is attributable to processes of tessera formation or processes that postdated tessera formation. These analyses have resulted in a list of craters that suffered tessera deformation prior to the emplacement of the global plains. The number density of these craters may then be used to constrain the duration over which tessera deformation occurred.

Methods. The rim crests of 81 craters intersect tessera terrain, representing 8.7% of the population of Venus craters. The 81 tessera craters we have identified include those that lie on a boundary between tessera and plains, thus giving an upper bound to the number of craters on tesserae. Comparison of our tessera crater database with two other published databases [4,5] shows agreement on 57 out of 115 reported craters; the major source of discrepancy is terrain definition, followed by disagreement in cases where the crater was on a small tessera outlier (10s km) or the crater itself was small (≤5km) or irregular. We have adopted a new detailed map of tessera terrain [6], increasing our confidence in both our terrain identification and values for tessera areas which are utilized in this study.

For a crater to be considered deformed, the deforming structure had to intersect the rim crest of the crater. We then strived to characterize the deformation that affected each crater as to style (compressional or extensional) and to type, i.e. is the deforming structure attributable to tessera or non-tessera processes? We define here tessera processes as being structures that are part of the local tessera fabric and can be traced to the edge of the tessera plateau where they are embayed by plains. Non-tessera processes include structures related to phenomena exterior to tesserae; for example, a crater on tessera fractured by a graben that emanates from a corona that lies within the plains.

Results. Of the 81 tessera craters identified, sixteen tessera craters are fractured (20% of tessera craters), nine of these are fractured by tessera processes (11% of tessera craters). No tessera craters are deformed by compression; all deformed tessera craters are modified by graben. To properly determine the importance of fractured craters on tessera, we rely upon the following observations made about tessera and venusian stratigraphy: 1) tessera cover ≈ 8% of the surface area of Venus [6], 2) tesserae comprise early compressional structures (Phase I deformation) superposed by later extensional structures (Phase II deformation) [7,8,9], and 3) tessera structures generally predate the venusian plains, the majority of which have wrinkle ridges [10]. The number of craters on tessera fractured by tessera processes thus represents an estimate of the age between the *cessation* of compression in the tesserae and the emplacement of the wrinkle-ridged plains that embay tessera structures. If we assume that the tessera have an average surface age of 300 Ma [2], the duration of Phase II tessera extension is (9/81)*300 Ma = 33±8 Ma, ≈10% of the average age of the venusian surface.

We now address the question of whether this 33 Ma estimate is applicable to all tesserae. We compared the number density of craters per tessera plateau for nine highlands larger than $1\times10^6 km^2$ and found that the number of craters per million km^2 cannot be distinguished with confidence (within 1σ error) from the global average of 2.07±0.07 craters/$10^6 km^2$ [2], nor from the average density for all tessera of 2.29±0.24 craters/$10^6 km^2$, supporting the assertion that the spatial distribution of craters on tessera cannot be distinguished from a random distribution [1,2,11]. Likewise, the number of craters fractured by tessera processes (range 0-33%) does not vary significantly between individual tessera highland plateaus nor from the average for all tessera (11%). While we acknowledge that the actual number of craters in these counts is small, these data show that fracturing on tesserae is a process with a wide spatial distribution affecting a similar percentage of craters on tessera terrain regardless of position on the planet.

Statistical Analyses. Using our new tessera crater database, we now compare the density of craters on the tessera to that of the plains (which refers to all terrain that is not tessera), extending to smaller crater sizes the work done by Ivanov and Basilevsky [3]. The tessera and plains crater populations were divided into $\sqrt{2}$ size bins and compared using the Fisher's Exact Test and found to be statistically indistinguishable, in agreement with previously published

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chi-square tests [2]. However, when the data are rebinned, the two populations are found to vary significantly (P value = 0.020) where at diameters <8 km, tessera have 1.9X less craters than the plains, and at diameters >8 km and >16 km, tessera have 1.4X more craters than the plains, consistent with previous studies [3]. There is no difference between the tessera and plains populations in crater diameter bins of <16 km, <32 km, or >32 km.

The deficiency of craters on tessera relative to plains at crater diameters <8 km corresponds to 10 actual craters missing on the tessera. However, because there are 40% more craters on the tessera than the plains at diameters >8 km and >16 km, we maintain that the distribution of craters on tessera should be 40% greater than the plains at all crater sizes. To model such a "corrected" size-density distribution for tessera craters, we smoothed the tessera and plains incremental size density distributions using a poisson regression based on a quadratic function and then calculated a new tessera distribution that was 40% greater than the observed plains distribution at all size bins. This "corrected" tessera distribution yields 15 craters <8 km and 18 craters <16 km missing on tessera relative to the observed plains distribution. If we add this maximum value of 18 missing craters to the 81 observed tessera craters, we get a new crater density for the tesserae of 2.80 ± 0.27 craters/10^6km^2, corresponding to an average surface age for tessera terrain of 405 ± 40 Ma, an age still within the limits of error of previous estimates [3]. We attribute the deficit of small tessera craters to the difficulty of distinguishing such small features and their ejecta in the complex tessera fabric, due to the influence of variable topography and high meter-scale surface roughness on the recognition of and perhaps deposition of crater rim and ejecta deposits at crater diameters <20 km [12].

Summary and Discussion. In summary, we found 81 craters on tessera terrain on Venus, 16 of which are fractured, 9 of these by tessera processes. By combining these observations with similar studies by other workers, we propose the following scenario for the evolution of the present venusian surface. The oldest structures on Venus are the compressional features (Phase I deformation) within tessera terrain; these features result from events that eradicated completely all craters on the surface of the planet. Compressional stresses ceased in the tessera, yielding to extensional stresses, producing the late-stage graben seen within the tessera (Phase II deformation). This period of extension may have completely destroyed some small craters (<16 km) in the tesserae, but it did not destroy large craters, as there are 40% more craters on tessera than the plains at craters diameters >16 km. Phase II tessera extension affected ≈10% of the present population of tessera craters. There is some evidence that this episode of tessera extension modified early regional fractured plains units [10,13], but this extension does not affect the widespread wrinkle-ridged plains that embay tessera structures. Thus the minimum duration between the cessation of compression in the tessera and the eruption of the wrinkle-ridged plains is ≈10% of the surface age of the planet, or ≈30 Ma. The broad-scale lava flooding producing the plains soon yielded to volcanism at discrete sources in the form of radiating dike swarms, rifts, coronae, flows, and volcanoes, respectively [14].

Constraints on Models of Venus Evolution. We apply our data to two end-member models for Venus evolution: a model of gradual thermal decay [15] and a model of catastrophic depleted mantle layer overturn [16]. The thermal decay model makes several major predictions that are not consistent with our data. First, tessera plateaus with high topography are predicted to deform more than tessera plateaus with low topography, however, we find that the density of craters fractured by tessera processes is statistically similar for tessera plateaus irrespective of elevation. A second prediction is that tessera highland deformation should abate gradually, however, we find that no craters on tessera record compression, requiring that compression in the tesserae occurred quickly or ceased rapidly relative to the rate of crater production. It is this attribute of our data that is most consistent with a model invoking a catastrophic genesis for tessera terrain, where the crater population on tessera is reset due to one or more compressive events.

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