Upwellings on Venus: Evidence from Coronae and Craters. D. M. Jurdy[1], P. R. Stoddard[2], and A. Matias[1], [1]Department of Geological Sciences, Northwestern University, Evanston IL 60208-2150, USA, donna@earth.northwestern.edu, [2] Department of Geology and Environmental Geosciences, Northern Illinois University, DeKalb IL 60115-2854, USA.

Introduction: Venus' surface underwent global resurfacing at about 300-500 m.y. ago, as estimated from impact crater counts [1]. Although our sister planet lacks apparent plate tectonic features, it has experienced tectonic and volcanic activity, some quite recently. Hundreds of coronae adorn its surface. These nearly circular features, ranging in size from 100 to 2600 km, may be caused by localized upwellings and thus be analogous to Earth's hotspots. The current deformation of Venus' surface has been attributed to a swell-push force, defined as the gradient of the geoid height [2]. Two likely areas of current geologic activity, Atla Regio and Beta Regio are marked by prominent geoid highs. We compare these two features using their coronae and craters to establish the nature and relative timing of the their formation.

The Regios: Atla and Beta Regios are both marked by pronounced topographic and geoid highs. Each lies at the intersection of multiple rifts - the chasmata system. Venus' chasmata system can be fit by great circle arcs at the 89.6% level [3]. When corrected for the smaller size of Venus, the length of the chasmata system measures [3], within 2.7% of the 59,200-km length of the spreading ridges determined for Earth by Parsons [4]. These, likely surface expressions of mantle upwellings, represent the most recent evidence of tectonic/volcanic activity on the planet. We examine the distribution, style, and attitude of coronae, and the location, and modification of craters with respect to these two geoid highs, noting the strong correlation of Earth's hotspots with its geoid highs [5].

Corona Classification: Corona formation on Venus could be caused by rising diapirs. Unlike Earth, Venus shows no evidence of horizontal motion, resulting in juxtaposition of its coronae of all ages. Also, there is little erosion to modify features. DeLaughter and Jurdy [6] have classified 394 coronae based on the morphology of the interior, terming them domal, circular, and calderic. They proposed that these differing styles reflect different stages in the evolution of a corona, from domal (youngest, perhaps still active) features, progressing through increasing degrees of collapse to the calderic coronae. Comparison of elevations of these features shows the domal coronae average higher elevations, and calderic at lower elevations, with circular in between. Jurdy and Stoddard [7] attempted to relate types of coronae to different chasmata in the Beta-Atla-Themis (BAT) region, the most volcanically active region of Venus. They suggest that the chasmata may also be of different stages of activity.

Craters: Impact craters on Venus are used to determine relative age and degree of modification of a region. Venus hosts approximately 940 craters, of which about 158 are tectonized, and 55 embayed, but only 19 planetwide are both tectonized and embayed [1]. Of these, four are near the crest of Atla, and one on its flanks, while Beta is home to three on its flanks and one on its crest. In addition, Beta and Atla have high relative percentages of craters that have been tectonized or embayed (Figure 1a, 1b). Although the

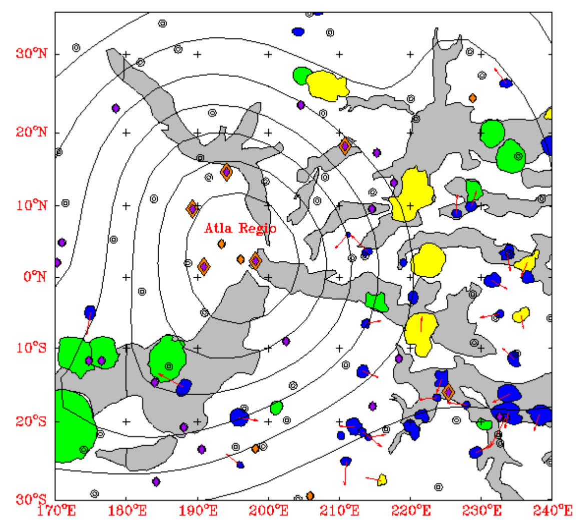

Figure 1a: The Atla Regio region. Geoid is indicated by 10-meter contours. Craters: small circles – unmodified; orange diamonds – embayed; purple diamonds – tectonized; purple within orange – tectonized and embayed. Grey regions indicate rifts. Corona color scheme same as in Figure 1. Red arrows indicate dip directions, where attainable.

overall global distribution of craters approximates random, areas with high concentration of altered craters clearly are more active. Most of the crest of Atla may still be active; otherwise some recent craters should be pristine. Indeed, Crater Uvayasi (2.3N, 198.2 about 38km diameter), one of only about 50 with parabolic dark halos - thought to be the youngest of all craters [8] - shows significant modification, both tectonic disruption and embayment by lava. We may therefore infer that Atla, with a higher percentage of altered craters, (8/17 or 47%, within three 10 meter geoid contours of the summit) than Beta (4/14 or 29%, in the same range) is a more active or recent feature than Beta. Both are younger than "average" terrain ((158 T + 55 E)/940 = 23%). Besides the evidence of tectonic/volcanic forces modifying craters, there exists a slight but systematic deficit of about 20-30 craters close to the chasmata [9].

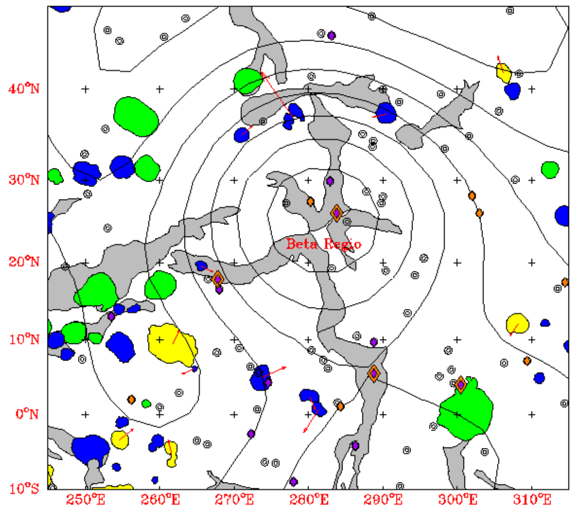

Figure 1b: The Beta Regio region. Symbols are the same as in Figure 1a.

Both Atla and Beta are ringed by many coronae, but neither has coronae at or near their crests even within 2 contours of their geoid highs (Figure 1a, 1b). Coronae do occur in many rift segments, yet none occurs at or near these intersection points. Perhaps just as remarkable, Atla has a partial ring of four domal coronae, all between 4 and 5 geoid contours from the crest, while Beta has a partial ring of 6 or so calderic coronae between three and four contours from its crest. In both instances, the rings parallel geoid contour lines. These are the nearest coronae of their type to the crests. If corona formation is contemporaneous with the uplift process at Atla and Beta, and if the domal are younger than the calderic coronae, then Atla should be more recent or active than Beta, in agreement with the modified-crater analysis. If these dating schemes are accurate, and uplift of Atla postdates formation of calderic coronae, then we would expect the latter to be tilted away from the center of uplift at Atla. Conversely, if calderic coronae formed concurrently with the uplift of Beta, (or domal formed concurrently with Atla uplift) then we would not expect to see such a pattern of dips. To test this, we determined the average dip of each corona (red arrows in Figure 1a, 1b). These determinations are at best very rough, but there is a suggestion that the calderic coronae dip away from Atla's crest, especially for those immediately west of the uplift. Neither the domal features at Atla nor the calderic features at Beta show such a pattern.

Conclusions: We use two independent schemes for assessing the relative timing of the uplift of Atla and Beta Regios. Both schemes, percentage of craters altered, and style of corona, suggest a younger age for the uplift of Atla. Another test of this result, orientation of the dip directions of coronae near each uplift, is consistent with the younger age for Atla. On the basis of dark halos, Basilevsky and Head [10] have also come to the conclusion that Atla younger than Beta. Our model is shown in Figure 2.

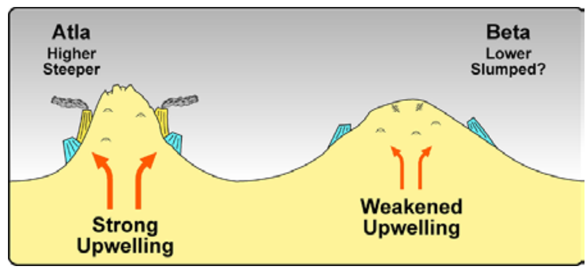

Figure 2: Schematic showing relationship between upwelling mantle and Atla and Beta Regios. Atla, presumably still active, has new, domal coronae (yellow) forming atop older, tilting calderic coronae (blue). Atla's crest should be in extension. Beta, no longer active, has begun to slump, tilting the calderic coronae towards the crest of the regio, which should be in compression.

References: [1] Phillips, R. J. et al. (1992) JGR, 97, 15,923-15,948. [2] Sandwell, D. T. et al. (1997), Icarus, 129, 232-244. [3] Jurdy, D. and Stefanick, M. (1999) Icarus, 139, 93-99. [4] Parsons, B. (1981) GJRAS, 67, 437-448. [5] Crough, S. T. and Jurdy, D. M. (1980) EPSL, 48, 15-22. [6] DeLaughter, J. E. and Jurdy, D. M. (1999) Icarus, 139, 81-92. [7] Jurdy, D. M. and Stoddard, P. R. (2001), LPSC XXXII, #1811. [8] Campbell et al., (1992) JGR, 97, p.16,249-16,277. [9] Stefanick, M. and Jurdy, D. M. (1996) JGR, 101, 4637-4643. [10] Basilevsky, A. T. and Head, J. W. III. (2002) JGR 10.1029/2001JE001584.