AGES OF VENUSIAN RIDGE BELTS RELATIVE TO REGIONAL PLAINS. G.E. McGill[1] and B.A. Campbell[2], [1]Department of Geosciences, University of Massachusetts, Amherst, MA 01003, gmcgill@geo.umass.edu, [2]Center for Earth and Planetary Studies, National Air and Space Museum, Washington, D.C. 20560, campbellb@nasm.si.edu.

Introduction: The nature of the global geologic history of Venus continues to be controversial. On one hand is a "directional" model [1,2] that involves a series of depositional and deformational events that are approximately coeval globally. On the other hand is a "non-directional" model [3] that does not require globally coeval events. Regardless of one's opinion of the directional model, it serves a very useful purpose because it is testable. The systematic evolution of volcanic styles that is inherent in the directional model is likely not real [3,4], and the implied single age for wrinkle ridge formation is demonstrably not correct [3,5,6,7]. An important element in the directional model is the proposed single age for formation of ridge belts. In the directional model these belts are globally older than the areally dominant regional plains [1,2]. This study is a test of this aspect of the directional model.

Results: It is clear that some ridge belts (or composite ridge/fracture belts) are older than the surrounding regional plains. A good example is Pandrosos Dorsa, the largest and most complex deformation belt in the Pandrosos Dorsa quadrangle [8]. Embayment and cross-cutting relationships clearly indicate that the fractures and ridges making up this belt are older than the oldest contacting regional plains unit [8,9]. Additional examples include Oya Dorsa and Poludnista Dorsa [10]. However, Laūma Dorsa, another belt in the Pandrosos Dorsa Quadrangle, provides evidence favoring formation of the ridges within the belt after the emplacement of the adjacent regional plains. Plains materials west of Laūma Dorsa have been interpreted to be members of the regional plains [8], or else flows that are superposed on, and thus younger, than the regional plains [11]. These plains west of Laūma Dorsa are superposed by a set of ~N-S trending wrinkle ridges. At several localities, one or more of these wrinkle ridges converge with Laūma Dorsa and grade gradually into typical deformation belt ridges several kilometers wide and several tens of kilometers long, indicating that the belt ridges result from folding of the regional plains. However, radar backscatter values on the flanks of these belt ridges do not match the backscatter of the plains, but it is possible that this difference in backscatter is due solely to the difference in local incidence angle created by the slopes on the flanks of the ridges. We next examine this possibility in some detail.

Conners [12] published expressions for the heights and angles of slopes inclined towards and away from the SAR beam. He correctly noted that there is generally no unique solution because each of these two expressions contains two unknowns (height and angle). However, belt ridges are almost certainly primary structural landforms; that is, they are anticlines with one limb sloping (dipping) towards the radar (the near limb), the other away from the radar (the far limb). It is reasonable to assume that both limbs will have similar height and slope angles (this assumption would be invalid only if there is a significant regional slope in the radar range direction). This allows us to solve the equations for the near and far limbs simultaneously (equations 1 and 2). Some results are listed in the table below.

1) $\mathbf{h = (tan\,\iota)(W_f - W_n)/2}$, where ι = the nominal incidence angle for the latitude in question, and $\mathbf{W_f}$ and $\mathbf{W_n}$ are the widths of the far and near limbs in the radar range azimuth.

2) $\alpha = \mathbf{h/(W/2)}$, where α = mean slopes (dips) of the fold limbs in the radar range azimuth, and **W** is the total width of the ridge in the radar range azimuth.

We next test if the difference in backscatter between the near and far limbs is due predominantly to variations in the local incidence angles that result from adding and subtracting the slope angle from the nominal incidence angle. We determine the SAR backscatter values from the MIDR image data directly [13], and the ratio of the measured near limb to far limb backscatter values can then be compared to the ratio of calculated backscatter values determined from the Hagfors equation using the modified local incidence angles. If we assume that the two limbs have essentially similar properties, and that the $\cos^4\iota$ term is negligible compared to the $C\sin^2\iota$ term, then the calculated ratio reduces to:

3) $\sigma_{0(n)}/\sigma_{0(f)} = [\sin(\iota - \alpha)/\sin(\iota + \alpha)]^{-3}$, where $\sigma_{0(n)}$ and $\sigma_{0(f)}$ are the radar backscatter values for the near and far limb, respectively.

The table below lists some results. The generally good agreement between the measured and calculated backscatter ratios indicates that the difference in backscatter between the near and far limbs of a ridge is due predominantly to differences in local incidence angles and not to differences in radar properties. The good agreement also indicates that the method for determining the ridge slope angles is valid.

Of greater interest is a test of the possibility that a belt ridge formed by folding the adjacent plains rather than by folding an older unit that now is embayed by the plains. This can be tested by comparing measured and calculated ratios of near- and far-limb backscatter strength to that of the nearby plains. Some results are listed in the table. The model developed here implies that the measured plains backscatter value must lie between the measured values for the near and far limbs of a ridge. If this is not true, then the ridge cannot have formed by folding the adjacent plains; but if this is true, then the ridge could have formed by folding the adjacent plains. If, however, a ridge is formed by folding an older unit with radar properties very similar to those of the adjacent plains, one would expect results similar to what we have obtained. Thus, where the measured and calculated ratios are similar it is possible but not proven that a ridge formed by folding adjacent plains.

Discussion: It commonly is difficult to determine exactly where the apparent crest and the near and far bases of a ridge are located when measuring the widths of the near and far limbs. Thus the ridge slope angles determined from equation 2) may be in error by 10% or more. Furthermore, the slopes determined by equation 2) imply a uniform slope from ridge crest to base, and thus are averages of what are almost certainly varying flank slopes. Simple open folds generally have limb slopes that more nearly approximate a sinusoidal than a planar shape. Thus the central portion of a ridge limb will slope more steeply than the calculated value and thus result in a smaller incidence angle than the one calculated using the results from equation 2). This central portion of the limb may dominate, resulting in additional uncertainty. We believe that measured and calculated ratios that differ by less than a factor of about 2 can be considered equivalent.

Even though the quantitative analyses described above cannot prove that some belt ridges formed by folding the plains materials that abut the belts, they do suggest caution in assuming that plains partially or completely surrounding a ridge are necessarily embaying the ridge and are thus younger. This result, combined with the apparent continuity of plains wrinkle ridges and belt ridges, indicates that not all ridge belts need be older than regional plains.

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Table sites

1. Unnamed belt, Lavinia Planitia Quadrangle (V-55)
   Ridge Height = 323m, ridge slopes = 9.4^0
2. Lukelong Dorsa, Pandrosos Dorsa Quadrangle (V-5)
   Ridge Height = 729m, ridge slopes = 5.3^0
3. Unnamed belt, Lavinia Planitia Quadrangle (V-55)
   Ridge Height = 263m, ridge slopes = 7.4^0
4. Aušrā Dorsa, Bereghinya Quadrangle (V-8)
   Ridge Height = 1,492m, ridge slopes = 14.7^0
5. Unnamed belt, Atla Regio Quadrangle (V-26)
   Ridge Height = 930m, ridge slopes = 16.1^0
6. Laūma Dorsa, Pandrosos Dorsa Quadrangle (V-5)
   Ridge Height = 243m, ridge slopes = 7.2^0

Slope is an apparent value in the radar range azimuth direction (specified in Connor's equations). This is the slope that the radar sees in any event.

σ_0 RATIOS (MEASURED,CALCULATED)

SITE	NEAR LIMB / FAR LIMB	NEAR LIMB / PLAINS	FAR LIMB / PLAINS
1	10.5,6.75	7.4,3.1	0.71,0.47
2	3.9,3.4	3.7,2.0	0.94,0.59
3	5.1,4.9	4.0,2.5	0.79,0.51
4	4.5,10.2	3.5,4.4	0.77,0.43
5	12.8,5.6	11.7,2.7	0.91,2.7
6	14.0,6.1	8.6,2.9	0.62,0.47