VISCOUS RELAXATION AS A PROBE OF HEAT FLUX AND CRUSTAL PLATEAU COMPOSITION ON VENUS.

F. Nimmo[1] , S.J. Mackwell[2], [1]University of California Santa Cruz, 1156 High St, Santa Cruz CA 95064, fnimmo@ucsc.edu [2] Rice University, Houston TX 77005, sjmackwell@gmail.com.

Introduction: Crustal plateaus are elevated, generally deformed regions on Venus, perhaps analogous to continents on Earth [1, e.g.].They are dominated by radar-bright, heavily-deformed terrain termed tessera. Recently, it has been proposed on the basis of infrared emissivity measurements [2–4] that tesserae are more felsic than the basaltic plains of Venus. If so, this is an important conclusion: granites - common felsic rocks – are rare on bodies other than the Earth, and are thought to form and ascend most readily in the presence of water. The existence of a possible ancient ocean on Venus is currently under debate [5,6], so confirming the presence of felsic rocks there, and granites in particular, would be of considerable interest.

Crustal plateaus have a tendency to undergo viscous relaxation over time [7,8]. The rate of relaxation depends on the rheology of the crustal material, the crustal thickness and the heat flux. Felsic materials relax more rapidly than basaltic materials, and wet mineralogies relax more rapidly than dry mineralogies. Thus, in principle the survival of elevated plateaus can be used to rule out certain mineralogies and water contents.

Petrology and Rheology. While the plains of Venus are basaltic [9], a few steep-sided domes on Venus imply such high viscosities that they must be silica-rich [10]. Extreme igneous fractionation could give rise to anorthosites on Venus [11], but the melt volumes involved may be too large to be plausible [4] . If Venus possessed an ancient ocean, then putative areas of vertical exchange between the near-surface and the mantle could give rise to felsic melts and hydrated minerals. The surface temperature of Venus of 450ºC means that hydrated minerals at the surface of Venus are likely to stay hydrated. At depth, however, dehydration reactions (and potentially melting) will occur.

We use the following flow laws for materials of interest: dry and wet anorthite from [12]; dry Columbia diabase from [13]; dry quartz from[14]; wet quartz from [15] ; dry albite from [16]. In all cases dislocation creep (n=3 for anorthite and quartz) is assumed.

Parameter Values. The mean surface age of Venus is probably in the range 0.3-1.0 Gyr [17]. The crustal thickness is somewhat uncertain, but the global mean value is likely between 20 and 30 km [18]. The surface heat flux is very uncertain, and is likely spatially variable. Most estimates find values larger than the expected radiogenic heat production rate of about 40 mWm^{-2}, but there is a large scatter in the values obtained.

Method: We use the method of [19] to track crustal plateau evolution. This assumes a temperature-dependent, non-Newtonian rheology with an axisymmetric geometry and Airy isostasy. The results are not sensitive to the behaviour of the mantle or the existence of a thin elastic lithosphere.

Results: Figure 1a shows the evolution of a model plateau topography over 450 Myr assuming a dry diabase (mafic) rheology. The initial conditions are taken from [8]. Although some relaxation occurs, the basic features of the crustal plateau are retained. In contrast, Fig 1b shows the same situation but now with a dry anorthite (more felsic) rheology. This time the relaxation is much more rapid and the final morphology is not consistent with observed plateau characteristics. Thus, for this particular set of conditions, felsic plateaus are not consistent with the observations.

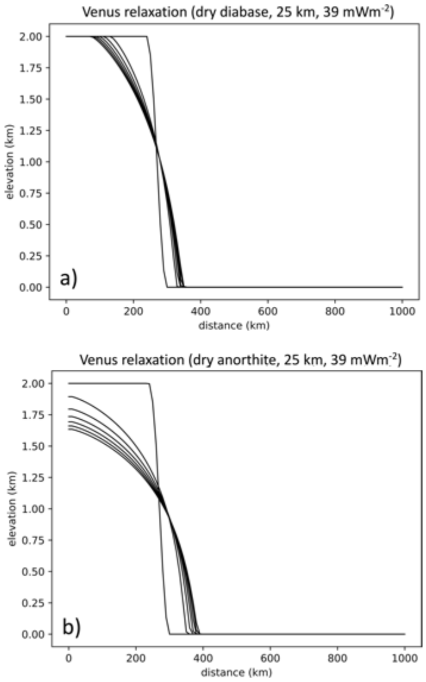

Figure 1. Elevation profiles plotted at intervals of 50 Myr from 0 to 450 Myr assuming a 25 km thick crust and a heat flux of 39 mWm-2. a) Dry diabase rheology. b) Dry anorthite rheology.

Figure 2 shows the relaxation time of our model plateau as a function of heat flux for six different rheologies. The relaxation time (30% relaxation of the central elevation) should not be less than the estimated surface age of about 1 Gyr (horizontal dashed line). If the background crustal thickness is 20 km (Fig 2a), neither dry nor wet quartz are permitted, and wet anorthite is only possible if the heat flux is less than radiogenic.

If the background crustal thickness is 30 km, dry anorthite and dry albite would require surface heat fluxes less than the lower and upper bounds on radiogenic heat, respectively. In all cases a dry diabase crustal plateau has no difficulty surviving over a 1 Gyr interval.

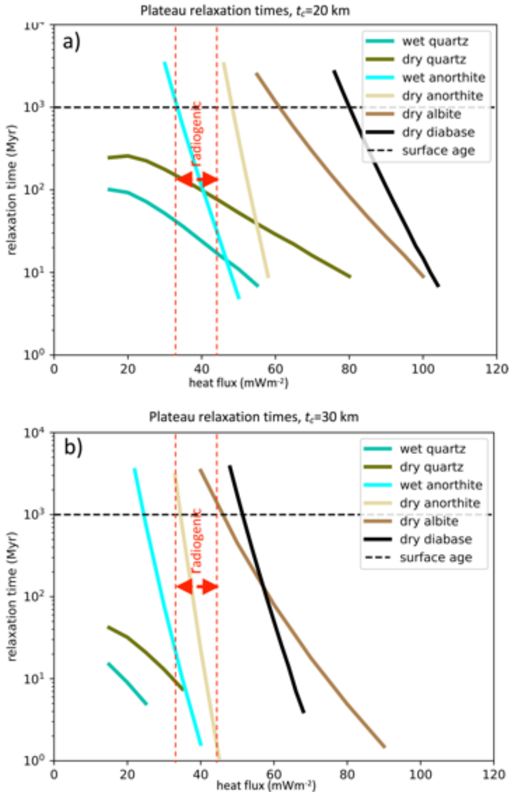

Figure 2. Relaxation timescale as a function of heat flux for different crustal rheologies. a) Background crustal thickness 20 km. b) Background crustal thickness 30 km.

Figure 3 shows the competing effects of crustal thickness and heat flux on relaxation times for wet and dry anorthite. These rheologies require background crustal thicknesses less than 20 km and 29 km, respectively, unless the heat flux on Venus is less than the present-day lower bound.

Discussion: The fact that crustal plateaus have not undergone extensive relaxation [8] can only be satisfied by limited combinations of rheology, heat flux and crustal thickness (Fig 3). For instance, quartz-rich rheologies can be ruled out (Fig 2). At present, however, heat flux and crustal thickness are too poorly known to be able to rule out dry anorthite-like rheologies.

Improved gravity measurements from the VERITAS and EnVision spacecraft will provide more reliable crustal thickness estimates and hence allow our constraints on rheology to be significantly tightened. They will also reveal whether mountain belts – which would provide more stringent relaxation constraints – are elastically supported or not.

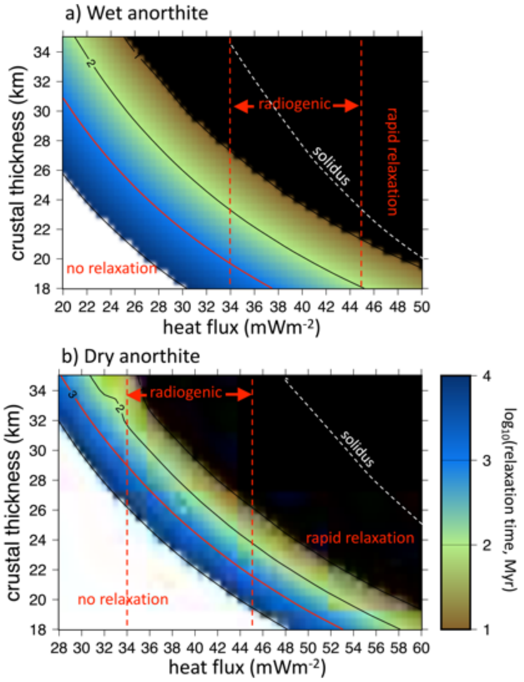

Figure 2. Relaxation time as a function of background crustal thickness and heat flux. Red curves denote 1 Gyr timescale. a) Wet anorthite. b) Dry anorthite.

Conclusions: Crustal plateaus are not quartz-rich – they would relax too rapidly. They could be anorthite-dominated, like parts of Mars or the Moon, but only if the local heat flux were less than the expected radiogenic value. Conversely, basaltic plateaus would maintain their topography with no difficulty for likely Venus parameter values. Future mission measurements will resolve whether crustal plateaus really are felsic or not.

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