HEAT FLOW DURING THE FORMATION OF RIBBON TERRAINS ON VENUS. J. Ruiz, Instituto de Astrofísica de Andalucía, CSIC, Camino Bajo de Huétor 50, 18008 Granada, Spain, ruiz@iaa.es.

Introduction: Ribbons are nearly rectilinear, large aspect ratio and closely spaced pairs of troughs and highs existing on many Venus' tesserae [1,2]. Tessera terrains constitute the oldest surface unit on Venus, are characterized by at least two sets of intersecting tectonic structures, elevated topography, and high surface roughness [3,4], and are mainly located in crustal plateaus [5]. Ribbons are usually interpreted as extensional features, but there is not consensus about their structural and temporal relations with other geological features [6,7].

Crustal plateaus could have originated related to zones of lithospheric downwelling and compression [8,9], or to the upwelling of mantle plumes beneath a thin lithosphere [5,10]. Rencently, an origin related to the progressive solidification of a huge magma pond [11] has been proposed. These models have very different implications for the thermal state of the lithosphere when crustal plateaus (and specifically ribbons) were formed.

Regularly spaced structural features are related to the thickness of a strong (brittle) layer above a weaker one acting as a level of decollement [12,13]. The rheological decollement associated to ribbon formation could be controlled by compositional stratification, but it is hard to have a compositional layer of closely uniform thickness along very large distances, moreover as regularly and similarly spaced ribbons are observed on spatially separated tesserae. So, with independence of structural and temporal relations between ribbons other features, this implies that ribbon spacing was related to the thermally-controlled brittle-ductile transition depth [2,14], which would ~1-3 km deep at the time when these features were formed [14].

Thus, ribbon spacing can be used to constraint the thermal state, and hence heat flow, of the upper crust at the time when these features were formed. Similarly, a previous work [6] estimated heat flows from ribbons by using geometrical criterions for estimate the brittle-ductile transition depth. For a brittle-ductile transition depth of 1-2 km, these authors found heat flows of 300-800 mW m^{-2} for dry diabase rheologies, values similar to those near to some terrestrial mid-ocean ridges.

Heat flow from brittle layer thickness: The thickness of the brittle layer is determined by the depth at which the brittle and ductile strength are equal. The temperature at the brittle-ductile transition depth can be obtained from the temperature dependence of ductile strength. In turn, the knowledge of the temperature at the brittle-ductile transition depth allows the calculation of the surface heat flow by matching to a temperature profile [15,16].

The brittle strength is calculated following the Byerlee's rule [17] for zero pore pressure and a crustal density of 2900 kg m^{-3}; in the case of Venus, and for shallow depths, the atmospheric surface pressure of 9.2 MPa must also be taken into account, is the atmospheric pressure at the venusian surface. In turn, we calculate the ductile strength by using a flow law appropriate for the dry diabase, considered representative for the extremely dry conditions of Venus. For creep parameters for dry diabase I use A = 30 MPa^{-n} s^{-1}, n = 4.7 and Q = 485 kJ mol^{-1}; these parameter values give the mean strength between those obtained for dry Columbia and Maryland diabases according to the experimentally obtained flow laws [18]. Strain rates between 10^{-17}-10^{-14} s^{-1} have been used. The heat flow is obtained assuming a linear thermal gradient, and a thermal conductivity of 2 W m^{-1} K^{-1}, a typical value for basaltic rocks.

Results for the present-day surface temperature: Figure 1 shows the heat flow in terms of the brittle-ductile transition depth (z_{BDT}) and strain rate, calculated for the present-day surface temperature, 740 K. The total range of heat flow consistent with z_{BDT} = 1-3 km is largely broad, ~130-780 mW m^{-2}, mainly because of uncertainties in both spacing/brittle layer thickness ratio and strain rate. The lower bound is lower than the obtained for dry diabase rheologies by [6], because that work was limited to $z_{BDT} \leq 2$ km and to a relatively fast strain rate of 10^{-15} s^{-1}.

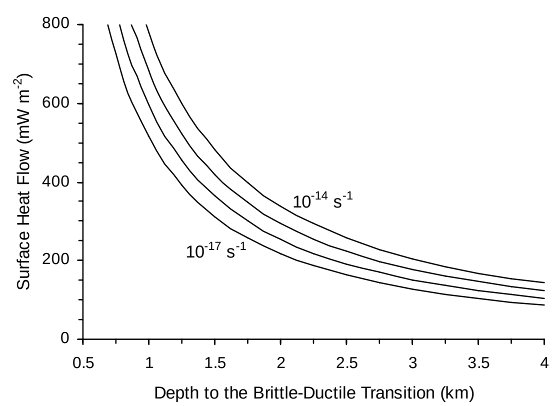

Figure 1. Heat flow in terms of the depth to the brittle-ductile transition, at the time when were ribbon terrains formed, calculated for a (present-day) surface temperature of 740 K. The curves are drawn for 10^{-17}, 10^{-16}, 10^{-15} and 10^{-14} s^{-1}.

In any case, the values obtained for ribbon terrains are clearly higher than whichever other estimation of surface heat flow proposed for Venus [19,20]. So, with independence of structural, genetic, and temporal relations of ribbons with other features, the thermal conditions leaving to the formation of ribbon terrains were different to those prevailing when other features were formed, with the exception, maybe, of short wavelength folds on tesserae. Morever, these heat flow values are very high, comparable to those typical of mid-ocean ridges, and it is not clear if they are reasonable for Venus. In any case, the results presented in Figure 1 are inconsistent with a downwelling-related origin for ribbon terrains.

Results for increased surface temperatures: It has been suggested that global volcanic events could affect the climatic history of Venus, maybe leading to episodic temperatures as high as 850-900 K [21,22]. An higher surface temperature implies a lower heat flow consistent with a given brittle-ductile transition depth. Figure 2 shows the heat flow in terms of surface temperatures between 700 and 1000 K, calculated for z_{BDT} = 2 km. For T_s = 850-900 K, the heat flow is 60-230; these values are greatly reduced with respect to those obtained for the present-day surface temperature. As a comparison, if the mean terrestrial heat flow of 87 mW m^{-2}, deduced from the last global compilation [23], is extrapolate for the venusion mass and raduious, the obtained value is 78 mW m^{-2}.

So, if the venusian surface environment was, at the time of ribbon terrain formation, ~100-150 hotter than today, the obtained heat flows could be consistent with venusian hotspots (although it does not favor any specific hotspot model), but hardly consistent with coldspot settings.

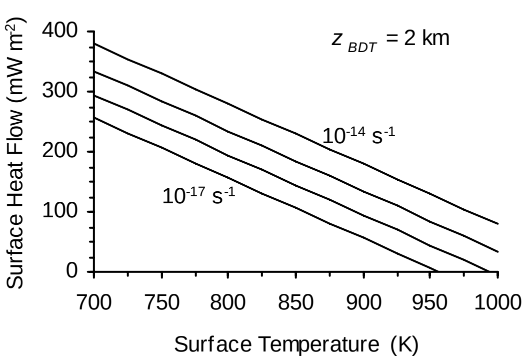

Figure 2. Surface heat flow as a function of the surface temperature, calculated for brittle-ductile transition depth of 2 km.

Conclusions: Heat flows calculated for ribbon terrains (at the time when ribbons formed) by using the present-day surface temperature are very high. Increasing surface temperatures as predicted by some models of climate forcing due to massive volcanism, reduces the surface heat flow to reasonable values for venusian hotspots. Otherwise, the results here presented are hardly consistent with a coldspot setting.

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