HOW DOES VENUS LOSE ITS HEAT? D.L. Turcotte, Department of Geological Sciences, Cornell University, Ithaca, NY 14853

On the earth about 75% of the heat flow through the mantle is attributed to subduction of cold lithosphere. In order to understand the tectonic and volcanic processes on Venus it is necessary to understand how heat is transported through the mantle of that planet.. Two general hypotheses have been proposed, the first is a near steady-state loss of heat as on the earth, the second is a strongly time dependent or catastrophic loss of heat. For the steady-state hypothesis the convective heat flux in the mantle must be attributed to either downward movement of cool delaminated lithosphere or upward movement of hot plumes. There is little surface evidence for the high required fluxes of either or both processes. The alternative is that Venus has not been losing significant heat for the last 500 Myrs., the lithosphere has been thickening by heat conduction and the interior is heating due to radioactive heat production.

Based on the near-uniform distribution of cratering on its surface, Schaber et al. [1] postulated that a global resurfacing event occurred on Venus about 500 Myrs. ago. Several authors [2, 3, 4] have argued that the lithosphere of the planet stabilized at that time. The extreme view is that the lithosphere has been thickening conductively since that time with no significant convective heat flux to its base. In this limit the thickness of the lithosphere is now near 300 km. Such a thick lithosphere is consistent with a number of observations:
i. it provides support for the high topography, up to 10 km.,
ii. it is consistent with the high observed geoid-topography ratios, up to 33 m/km [5],
iii. it is consistent with the observed unrelaxed craters [6],
iv. and it is consistent with the thick elastic lithospheres inferred from flexural studies [7].
In this limit the radioactive heat release heats the interior of the planet. Assuming that the concentrations of heat producing elements within Venus are equal to those within the earth the increase in temperature in 500 Myrs. is about 100 ^{o}K.

Based on a scaling with the earth the total heat production within Venus is estimated to be 3×10^{13} W. It is necessary to transport this heat through the mantle by convective processes. One mechanism is the delamination of the base of the lithosphere, the descent of the cool lithospheric rock cools the mantle. Assuming that the temperature difference across the delaminated layer is 400 ^{o}K and its thickness to be 20 km, it is necessary to completely delaminate the entire lithosphere of Venus every 7 Myrs. This could happen if the viscosity of the mantle is very low, near 10^{18} Pa s, but there is no surface evidence for regular global delamination and it is very difficult to envision such a low mantle mantle viscosity.

A second mechanism for the vertical ascent of heat is a high plume flux. The strongest plume on the earth is the Hawaiian and it is estimated to have a heat flux of 4×10^{11} W [8]. Thus nearly 100 Hawaiian strength plumes would be required to transport heat through the mantle of Venus. With a relatively thin lithosphere, it would be expected that both surface swells and massive surface volcanic eruptions would be associated with strong mantle plumes on Venus. Beta Regio certainly has many of the surficial features associated with a mantle plume, Atla, Eistla, and Bell Regiones may also represent plumes. But the number and volume of surface volcanism would indicate that the vertical flux of heat associated with plumes on Venus would be only a small fraction of the total required vertical heat flux.

The heat flow from the mantle can be reduced if a significant fraction of the heat producing elements are concentrated in a relatively thin crust. Heat can then be conducted through the crust to the surface. Based on concentration measurements taken by Vega and Venera landers [9] a crustal heat production near 1.4×10^{-10} W/kg is indicated, about a factor of 20 greater than the mantle. A global crust 50 km thick would include about 40% of its heat producing elements, the temperature at the base of the crust would be about 1600 ^{o}K. A thinner crust would contain a lower percent of the heat producing elements, a thicker crust would be molten at its base. With such a high crustal temperature, a very low mantle viscosity would be required to extract the remaining heat from the mantle.

Observational evidence appears to strongly favor a thickening lithosphere on Venus. But the question of heat loss from the mantle of Venus remains. As the lithosphere thickens its gravitational instability increases, also the heating of the mantle will have reduced its viscosity by an order of magnitude in 500 Myrs. Both could contribute to a relatively rapid global subduction event.. The cooling associated with such an event would be equivalent to over 50% of the accumulated mantle heating. After a global subduction event a period of very high surface heat flow would be expected to occur. However, conditions for the initiation of subduction on the earth are not established, so applicable criteria are not available.

1. G.G. Schaber, R.G. Strom, H.J. Moore, L.A. Soderblom, R.L. Kirk, D.J. Chadwick, D.D. Dawson, L.R. Gaddis, J.M. Boyce, and J. Russell, J. Geophys. Res. 97, 13,257 (1992).
2. J. Arkami-Hamed and M.N. Toksoz, Phys. Earth Planet. Int. 24, 232 (1984).
3. R.G. Strom, J. Arkami-Hamad, and M.N. Toksoz, Lunar Planet. Sci. XXIII, 1379 (1992).
4. D.L. Turcotte, J. Geophys. Res. 98, 17,061 (1993).
5. S.E. Smrekar and R.J. Phillips, Earth Planet. Sci. Let. 107, 582 (1991).
6. R.E. Grimm and S.C. Solomon, J. Geophys. Res. 93, 11,911 (1988).
7. D.T. Sandwell and G. Schubert, Science 257, 766 (1992).
8. N.H. Sleep, J. Geophys. Res. 95, 6715 (1990).
9. Yu.A. Surkov, F.F. Kirnozov, V.N. Glazov, A.G. Dunchenko, L.P. Tatsy, and O.P. Sobornov, J. Geophys. Res. 92, E537 (1987).