TABLE 1. Thermal Properties of Lava Flows on Venus and Earth

T_o, K	F_F, kW m^{-2}	F_N, kW m^{-2}	F_R, kW m^{-2}	F_T, kW m^{-2}	t, s	C
			Venus Highlands			
1500	24.27	80.22	207.8	288.5	5.66×10^{-1}	0.27 mm
1300	19.46	59.34	113.9	173.5	2.01×10^{1}	4.32 mm
1100	14.52	39.53	54.7	94.2	1.68×10^{2}	16.0 mm
900	9.01	20.40	20.3	40.7	1.64×10^{3}	57.1 mm
700	2.02	2.67	2.6	5.3	1.53×10^{5}	0.60 m
680	1.22	1.38	1.5	2.9	5.30×10^{5}	1.13 m
660	0.41	0.32	0.5	0.9	5.73×10^{6}	3.73 m
			Venus Lowlands			
1500	44.08	122.40	201.9	324.3	4.48×10^{-1}	0.24 mm
1300	33.35	84.21	108.1	192.3	1.64×10^{1}	3.90 mm
1100	22.66	49.68	48.8	98.5	1.54×10^{2}	15.3 mm
900	10.63	17.77	14.5	32.3	2.60×10^{3}	71.9 mm
800	3.77	4.39	4.0	8.4	4.89×10^{4}	0.33 m
780	2.30	2.26	2.3	4.6	1.70×10^{5}	0.62 m
760	0.77	0.53	0.7	1.5	1.67×10^{6}	1.95 m
			Earth			
1400	6.47	11.10	162.4	173.5	5.13	1.36 mm
1300	6.10	10.00	121.0	131.0	2.54×10^{1}	4.38 mm
1100	5.12	7.88	61.9	69.8	2.53×10^{2}	18.8 mm
900	4.14	5.85	27.5	33.4	2.14×10^{3}	63.4 mm
700	3.01	3.76	9.9	13.6	2.08×10^{4}	0.22 m
500	1.59	1.60	2.3	3.9	3.73×10^{5}	0.99 m
400	0.87	0.70	0.7	1.6	2.61×10^{6}	2.69 m
330	0.27	0.15	0.16	0.43	4.02×10^{7}	10.8 m
310	0.09	0.034	0.05	0.14	3.90×10^{8}	33.8 m

Lava surface temperature: T_o; forced convection, natural convection, and radiation heat loss fluxes: F_F, F_N, and F_R, respectively; total heat loss flux: F_T; time since eruption of the lava: t; thickness of solid crust on the surface of the flow: C.

calculated using W = 1 m/s on Venus [Marov et al., 1973; Avduevskii et al., 1976; Counselman et al., 1980; Seiff et al., 1980] and W = 10 m/s on Earth. The value of L used is 1 km for both planets and probably lies within a factor of 10-30 of the appropriate value for most flows. Examination of equations (3), (4), and (6) shows that F_F varies only as the fifth root of L, so that a thirty-fold error in L will yield only a factor of 2 error in F_F.

If the ambient wind speed is sufficiently small, natural convection takes over from forced convection and the relevant relationship is

$$Nu = 0.14\ (Gr\ Pr)^{1/3} \quad (7)$$

where now the naturally convected heat flux per unit area, F_N, replaces F_F in equation (4); Pr is still given by equation (5), and Gr is the Grashof number:

$$Gr = \frac{g\alpha\ (T_0 - T_e)\ L^3\ \beta^2}{\mu^2} \quad (8)$$

in which g is the acceleration due to gravity and α is the volume expansion coefficient of the gas. Substitution of (4) and (8) into (7) shows that F_N is independent of L, the size of the flow.

Comparison of the values of F_F, F_N, and F_R given in Table 1 shows that radiative heat losses dominate convective losses for terrestrial flows until the surface temperature falls below about 500 K. In contrast, convective losses are much more important on Venus, mainly due to the high atmospheric gas density, and even if forced convection is absent, natural convection losses exceed radiation losses at temperatures below about 1000 K. The total heat loss rate from a Venusian flow surface F_T, taken to be the sum of the radiative loss and whichever of the forced and natural convective losses is the greater, is seen to be about 1.5 times larger than the corresponding rate for a terrestrial flow at the same temperature at temperatures exceeding about 900 K.

The two aspects of lava flow cooling which are most relevant to the comparison of flows on Earth and Venus are the variations with time since leaving the vent of (1) the temperature T_0 of a given element of the flow surface, and (2) the thickness C of its rigid crust defined here as the depth at which the solidus temperature T_S is reached. T_S is taken as 1525 K on Venus and 1475 K on Earth on the basis of the thermal arguments presented earlier. Settle [1979a] has stressed the importance of latent heat release in retarding the interior cooling of lava flows, and we use an analysis based on this principle given by Turcotte and Schubert [1982]. C is given as a function of time t by

$$C = 2\lambda\ (\kappa t)^{\frac{1}{2}} \quad (9)$$