N94-16282

# THE COOLING RATES OF PAHOEHOE FLOWS : THE IMPORTANCE OF LAVA POROSITY.

**Alun C Jones, Institute of Environmental& Biological Sciences, Lancaster University , Lancaster LA1 4YQ, U.K.**

Many theoretical models have been put forward to account for the cooling history of a lava flow (1, 2, 3, 4), however only limited detailed field data exist (5, 6, 7, 8) to validate these models. To model accurately the cooling of lava flows, data are required, not only on the heat loss mechanisms, but also on the surface skin development and the causes of differing cooling rates. This paper argues that the cause of such variations in the cooling rates are attributed, primarily, to the vesicle content and degassing history of the lava.

The cooling rates of 20 pahoehoe lobes on the slopes of Kilauea's South East Rift were obtained using two Minolta hand held Cyclops thermal infrared thermometers. The instruments, C330 and C52, obtained surface temperatures by recording emitted radiation from the flow surface in the wavelength ranges of 0.8 to 1.1 µm and 8 to 13 µm; temperatures were obtained at 0.5 s intervals and both instrument view angle resulted in surface target diameters of < 2 cm.

There are two parts to each curve (Fig 1): a high temperature part characterised by a steep, smooth profile and a low temperature part characterised by a shallower, uneven profile. The best fit equation between surface temperature (T / °C) and time (t /s), for all flows monitored, where the surface temperature was > 600 °C was exponential; e.g. $T = 1154 * 10\hat{}(-2.7e^{-3t})$, (Correlation coefficient, $C_c$ = 0.76). For surface temperatures < 600°C the best fit equation was logarithmic, e.g. $T = 773.5+(-157 \text{ Log } t)$ ($C_c$ = 0.84). When the whole flow profile is considered the best fit equation is again logarithmic, e.g. $T = 1099 + (- 165 \text{ Log } t)$, ($C_c$ = 0.94). From the time of lobe extrusion to the time where the surface cooled to 600°C, the lava was incandescent and heat was lost predominantly by radiation, and therefore the relationship between temperature and time is exponential. After the formation of the crust between 600 and 550°C, conduction through the thickening crust and convection away from the surface becomes the dominant heat transfer processes (2), and the relationship between temperature and time becomes logarithmic. The development of such a crust is a significant factor in controlling the final dimensions of the lava lobes. The cooling profiles obtained from the surfaces of pahoehoe lobes (Fig 1), with similar dimensions (flow thicknesses between 10 and 45 cm), show that flows cool at differing rates, and as they solidify the differences between their cooling profiles become exaggerated. A number of parameters which may influence the cooling rates, e.g. flow effusion and stagnation rates; flow field topography; distance from source; lobe position on flow field; residence time of lava within a tube system; and weather conditions, (chemical differences are ignored as these lavas can be considered as chemically homogeneous) have been studied and discounted (9). The one parameter which differed significantly in all flows monitored was the lava porosity.

Three distinct types of pahoehoe have been recognised on the basis of their porosity: (i) vesicle-rich lava termed spongy pahoehoe (S-type), (ii) vesicle-poor lava termed pipe pahoehoe (P-type) (10) and (iii) dense pahoehoe (D-type) (9). D - Type pahoehoe (porosity <29%) has a vesicle content lower than P-type (30 - 39%) and S - Type ( >40%), cools noticeably slower than the other lava types and has a higher surface temperature upon extrusion from the tube system (9).

As radiative heat transfer across the vesicles is more effective than conduction through the surrounding solid basalt, the presence or absence of vesicles will affect the rate at which heat is lost from the interior of the lobe. This leads to the conclusion that the cooling rates of lobes are sensitive to their vesicle population and this is reflected in the gradient of the cooling profiles (Fig 1).

The relationship between these cooling profiles however cannot be quantified as each have different initial temperatures and it is uncertain as to amount of cooling the lobe has undergone prior to the start of monitoring. Cooling profiles obtained from the surface of Kupaianaha lava pond (11), during its eruptive periods provided a near complete cooling profile of lava between 1153 and 280 °C. This cooling profile is used as a base line against which the incomplete cooling profiles obtained from pahoehoe lobes can be matched against (Fig 2). For this method it is assumed that the cooling history of a lobe, prior to being recorded, cooled from an initial temperature of 1153 °C along the pond profile, to the temperature at which the thermometer started recording the lobe. Thereafter the cooling profile deviated from the pond profile, due to differences in the volatile content of the lava.

Although the vesicle population of lava in the pond and the lava extruded on to the flow field are extremely different (9), the differences in the gradient of each profile only becomes significant during the later stages of the cooling history of the lobe. Using the profiles for which the lobe porosities are already known (from field samples of lobes monitored) the remaining unknown porosities were determined by calculating the relationship between the various profiles (3).

The above however, may not be the case for larger flows, i.e. channelised pahoehoe and a'a, where the flow dimensions can be an order of magnitude greater than those of pahoehoe lobes, and an increase in flow thickness will, almost certainly, influence the cooling rate of the flow. This work shows how remotely sensed thermal data can provide an insight to the mechanisms of flow cooling and highlights the significance that lava porosity has on the cooling rates of such bodies. When modelling the cooling and morphology of terrestrial or planetary sheet and lobate flows, the porosity and degassing history must therefore be considered and accounted for.

References: (1) Baloga, S.M. & Pieri, D.C (1986). J. Geophys. Res. 91, 9543-9552. (2) Head, J.W. & Wilson, L. (1986). J. Geophys. Res. 91, 9407-9446. (3) Pieri, D.C. & Baloga, S.M. (1986). J. Volcanol. Geotherm. Res. 30, 29-45. (4) Crisp, J. & Baloga, S.M. (1990). J. Geophys. Res. 95, 1255-1270. (5) Pinkerton, H & Sparks, R.S.J. (1978). Nature. 276, 383-384. (6) Lipman, P.W. & Banks, N.G. (1987). U.S.G.S. Prof. Paper 1350, 1527-1568. (7) Neal, C.A. et al., (1988). U.S.G.S. Prof. Paper 1463, 99-127. (8) Flynn, L.P. & Mouginis-Mark, P.J. (1992). Geophys. Res. Lett. 19, 1783-1786. (9) Jones, A.C. (1992). Ph.D. Thesis, Lancaster. (10) Walker, G.P.L. (1989). Bull. Volcanol. 51, 199-209. (11) Jones, A.C. et al. (1990). IAVCEI absts, Mainz.

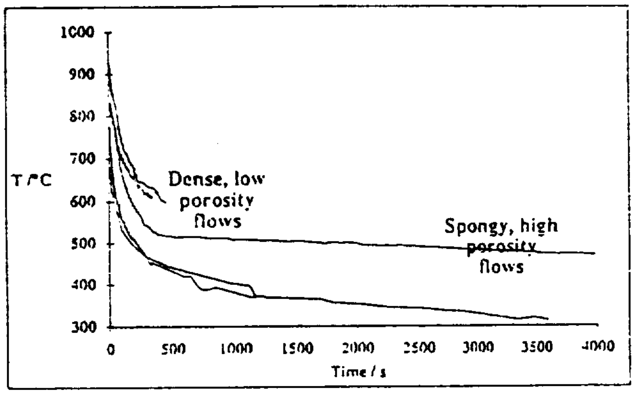

Fig. 1 Cooling profiles from the surfaces of pahoehoe lobes. The dense flows begin to flatten out before the spongy flows.

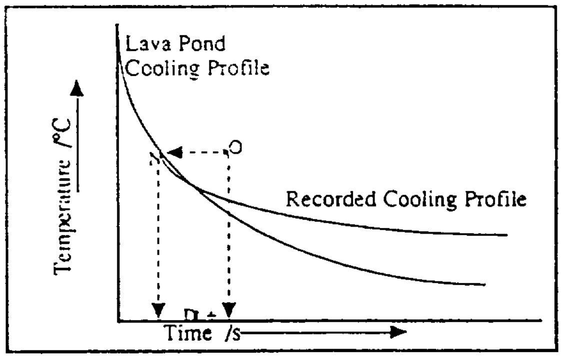

Fig. 2 Method of correcting the cooling profiles of flows against the pond profile
The origin of the flow profile (O) is moved to the corresponding temperature on the pond curve(N), and the time difference (Dt) is added to the original flow data.

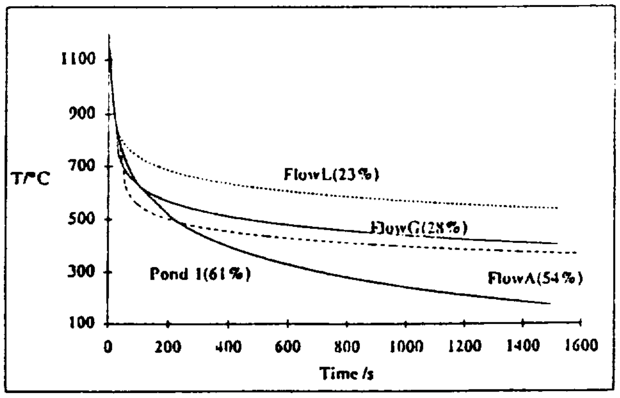

Fig. 3 Importance of porosity (%) on the cooling rate of flows is shown, using best fit equations for flows whose porosity is known.