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Cooling Rate Profile of a Lava Flow

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The physical properties of lava flows are strongly influenced by the cooling rate. During rapid heat loss, the structure of a melt undergoes a transition to a brittle behavior, referred to as the glass transition temperature (T_g). T_g is dependent on the cooling rate. Field observations commonly reveal that the cooling of a lava flow occurs by heat loss from the top and bottom. This results in the boundaries of the flow cooling to T_g rapidly while the core of the lava flow remains ductile and deforms readily. Thus, the thermal history of the lava flow is an important factor in its emplacement, and data of the cooling rate is necessary in understanding and predicting the length of the flow path. In this study, we investigate the vertical cooling profile of a phonolitic lava flow (Tabonal Negro) in Tenerife, Spain via a series of calorimetric analyses. Differential Scanning calorimeter (DSC) measurements were performed on 14 natural glass samples to characterize the rate at which the glass transition range was crossed. Specifically, the heat capacity (C_p) was measured for different heating/cooling cycles to obtain a set of kinetic parameters that were used to fit an initial C_p curve. Cooling rates ranging from 0.05 to 10 $Kmin^{-1}$, and T_g (peak) between 874 K and 934 K were obtained. As hypothesized, a gradient in cooling rates were observed, with the high rates occurring at the margins of the flow. This gradient is far from symmetric along the vertical cooling profile and exhibits a minimum at $\sim$ $2/3$ of the flow thickness, seen from the top. In a simplistic 1-dimensional model the cooling rate distribution is reproduced, and a few basic scenarios have been tested to understand the thermal history of the lava flow. The results of this model emphasize the importance of the insulating properties of crust growth in a lava flow and it supports the calorimetric data.