TUBULAR HELLS: NEW MEASUREMENTS OF LUNAR MAGMA RHEOLOGY AND THERMAL PROPERTIES APPLIED TO THERMAL EROSION AND LAVA TUBE FORMATION A.G. Whittington[1], A. Sehlke[2] and A.A. Morrison[1,3], [1] University of Texas at San Antonio, Geological Sciences, One UTSA Circle, San Antonio TX 78249, alan.whittington@utsa.edu, [2]NASA Ames, Mountain View, CA 94043, [3]Geological Sciences, University of Missouri, Columbia MO 65211, aaron.morrison@utsa.edu

Introduction: Lava tubes are potential sites for habitation on the Moon and other bodies, as long as their roofs are intact. Tubes form where surface flows develop solidified insulating roofs, allowing long-distance transport [1,2], and frequently erode down into their substrate [3,4]. There are more than 200 sinuous rilles on the Moon, thought to be channelized lava flows, and thermal erosion was probably the dominant incision mechanism in over 75% of these [5]. While the vast majority of rilles are associated with the lunar mare and Procellarum-KREEP terrane, some emerge from the anorthositic highlands and flow into the mare [5]. Potential lava tubes have also been identified by the presence of pits interpreted as skylights in an impact melt sheet associated with the crater Philolaus near the lunar north pole [6], although most pits in impact melts may result from collapse into voids formed during protracted cooling of a stationary melt sheet [7].

Controls on Thermal Erosion: The efficiency of thermal erosion depends strongly on magma physical properties including viscosity and density, thermal properties including heat capacity, thermal conductivity, and enthalpy of crystallization, and on environmental factors including ground slope and substrate composition [8]. The physical and thermal properties depend strongly on magma composition [9, 10, 11], which on the Moon include several subgroups of lunar mare basalt, and KREEP basalt.

Once lavas begin to crystallize, their rheology depends on strain rate as well as the shape- and size-distribution of the crystal cargo [9]. Models require increasingly large and tenuous extrapolation, and the best approach is direct measurement.

An example using KREEP: We studied the rheological evolution of a crystallizing lunar KREEP analog by concentric cylinder viscometry. At the liquidus temperature of 1220 ℃, liquid viscosity is ~50 Pas, similar to Hawaiian lavas [10]. At successively lower temperatures, crystal fraction and effective viscosity both increased (Fig. 2). By 1177˚C the crystal fraction was ~17 volume %, and the viscosity had increased to >1000 Pas.

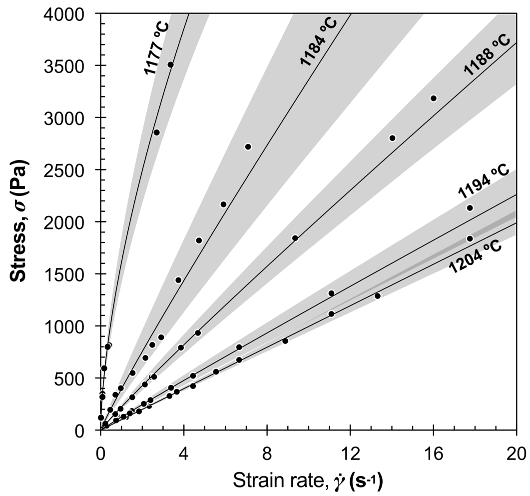

Figure 1. Rheological data and best-fit flow curves. Note non-Newtonian behavior (shear-thinning) at lower temperatures and higher crystal fractions.

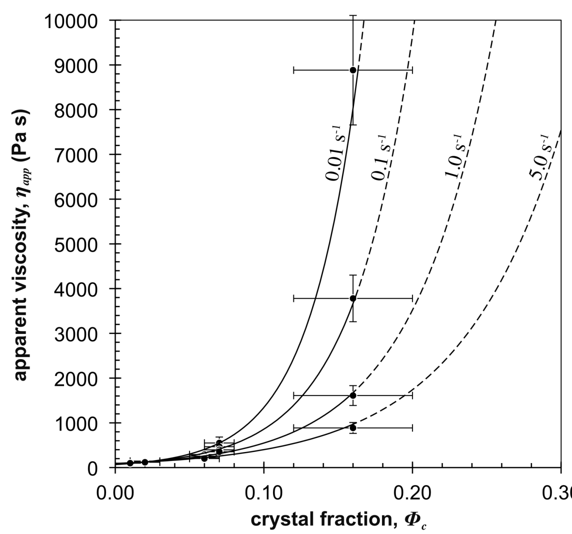

Figure 2. Apparent viscosity vs crystal fraction. Note the rapid increase in viscosity and importance of strain rate in determining apparent viscosity.

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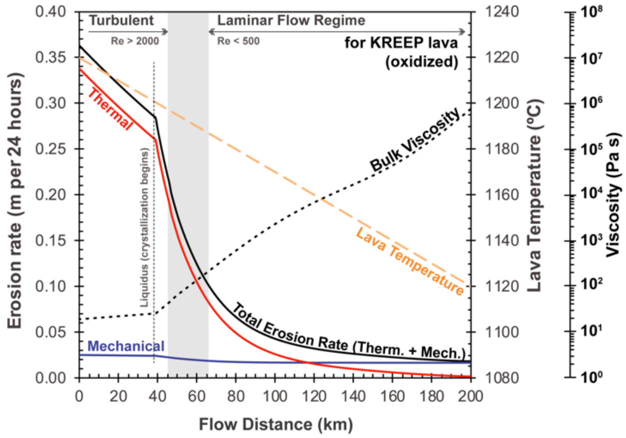

Figure 3. Temperature, bulk viscosity, flow regime, and erosion potential of KREEP lavas..

Example calculations are shown in Figure 3, for thermo- mechanical erosion rate as a function of flow distance for a KREEP analog basalt erupted on the lunar surface with a continuous channel width of 480 m and lava thickness of 10 meter on a slope of 0.2˚. Erosion rate quickly diminishes upon cooling below the liquidus due to increasing viscosity (in turn lower flow velocity and strain rate). Viscosity calculations include yield strength of the lava. The gray band indicates transition from turbulent to laminar flow regimes shortly after lava cools below the liquidus. This basic model assumes a constant cooling rate of the lava erupting about 20 ˚C above the liquidus temperature.

Future work: The possibility of lava tubes forming in impact melt sheets opens up a much wider array of compositions (from anorthosite liquid through the mare liquid, and everything in between) for study [12]. In addition, these superheated lavas may be much more effective at forming lava tubes than normal volcaniclava flows.

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