AMBIENT EFFECTS ON BASALTS AND RHYOLITES ON VENUS AND EARTH; N.T. Bridges, Dept. of Geology and Geography, University of Massachusetts, Amherst, MA 01003

A host of interdependent factors control the morphology of lavas, not the least of which are those of the ambient environment. Recently, comparisons of volcanic structures on Venus and the subaqueous and subaerial environments of Earth have been made (1-3). In light of these investigations, the influence of the ambient environment are evaluated for silicic and basaltic flows. Examined are the effects of ambient density and temperature, which control the relative amounts and rates of radiative and convective fluxes from the flow surface and pressure, which controls the solubility of volatiles in the melt and the degree of vesiculation. In addition, the effect of density on buoyancy (specific gravity) is discussed.

As magma rises toward the surface, bubble nucleation followed by expansion occurs (4). Although the exsolution of gasses begins within the conduit, a significant amount continues after flow emplacement, both as fluids coming out of solution in the lava and as a "second boiling" process releasing gasses upon crystallization. Empirical values of basalt vesicle content and density as a function of ambient pressure are known from rocks dredged from varying depths on the seafloor (5,6). A common, although nonunique, vesicle content for subaerial basalts is 30 volume percent with a density of 2500 $kg \cdot m^{-3}$. At a depth of 900 m, analogous to the 90 bar pressure on Venus, vesicle content is about 10 vol. % and densities are ~ 2800 $kg \cdot m^{-3}$. At ocean depths of 4500 m basalts have vesicle contents of only a few tenths of volume percent and densities on the order of 3000 $kg \cdot m^{-3}$. Similarly, a typical terrestrial rhyolite of a density of 2220 $kg \cdot m^{-3}$ with 30% vesicles should have 10% vesicles on Venus and a density of 1950 $kg \cdot m^{-3}$. As vesiculation increases, the specific heat and conductivity decrease by proportional amounts, mirroring density (7). A specific heat for rhyolite and basalt of 1200 $J \cdot kg^{-1} \cdot K^{-1}$ with 0% vesicles is lowered to 1080 and 840 $J \cdot kg^{-1} \cdot K^{-1}$ with 10 and 30% vesicles, respectively. Similarly, rock conductivity decreases by about 10 and 30%, respectively. The change in these three variable, in turn, changes the thermal diffusivity by an equivalent amount. Thus, a basalt diffusivity of 6.0×10^{-7} $m^2 \cdot s^{-1}$ on land (8), would be 5.4×10^{-7} $m^2 \cdot s^{-1}$ on Venus and 5.0×10^{-7} $m^2 \cdot s^{-1}$ on the seafloor. A rhyolite on Earth with a diffusivity of 7.5×10^{-7} $m^2 \cdot s^{-1}$ (9) would have a value of 6.7×10^{-7} $m^2 \cdot s^{-1}$ on Venus.

These parameters will affect the rate at which lava cools. Heat loss was modeled using a half-space of a given density, specific heat, and conductivity cooled by convective and radiative fluxes (10). The surface temperature as a function of time was found using both lava physical properties appropriate to those in subaerial conditions and more realistic values as discussed above (Table, Figure 1). It is found that rhyolite and basalt erupted subaerially on Earth at temperatures of 1423 K and 1073 K, respectively, will reach their glass transition temperatures (1003 K and 943 K [11]) in 13 and 68 seconds, respectively. Basalt on Venus with physical properties appropriate to those on Venus takes 58 seconds to reach the glass transition temperature. Basalt on Venus that has terrestrial subaerial physical properties takes 31 seconds to reach the glass transition. Rhyolite will reach its glass transition temperature in 15 seconds assuming Venusian physical properties and 8 seconds using terrestrial ones. Basalt at a depth of 4500 m on the seafloor will solidify in 0.1 second if lava parameters appropriate to the seafloor are assumed and 0.04 second assuming subaerial values. Thus, neglecting changes in physical properties of lava flows underestimates cooling times by a factor of two or more on Venus and the seafloor.

The solubility of H_2O in lava is proportional to the ambient pressure. At the 90 bar pressure of Venus, the H_2O solubility in basalt at 1100 °C (12) and granite at 700 °C (13) is 0.6 wt % . At a confining pressure of 450 bars appropriate for the seafloor, basalt solubility is 1.7 wt %. Dissolved water decreases the melt viscosity. Dry basalt at 1100 °C with an original viscosity of 200 Pa·s, decreases in viscosity to 100 Pa·s and 70 Pa·s, for the H_2O solubilities appropriate for Venus and the seafloor, respectively (14). For granite at 800 °C, a dry viscosity of 10^{10} Pa·s decreases to 10^8 Pa·s for Venus (14). Therefore, the outer surface of rhyolites on Venus should have viscosities two orders of magnitude less than equivalent lavas on Earth. Basalt outer surfaces will be least viscous on the seafloor, slightly more on Venus, and twice as much on land. CO_2 and SO_2 are less soluble than H_2O and should not have an appreciable affect on lava viscosity at these pressures.

Finally, the interplay between viscosity and buoyancy determines flow height. For a given extrusion rate, flow height scales as $(v/g')^{1/4}$, where v is the kinematic viscosity and g' the specific gravity or buoyancy (15). On Venus, buoyancy is largely negligible, so that the effects of a lower viscosity due to ambient pressure are not offset like they are for basalt on the seafloor. The greater dependence of viscosity on pressure for silicic flows compared to basaltic ones should cause rhyolite lavas to be about 1/3 the height of rhyolite flows on Earth. Basaltic flows should be about the same height in all three environments.

If flows are significantly thick, degassing will be inhibited in the flow interior and physical properties will be largely independent of ambient conditions. Thus, structures formed from thick flows, especially if emplaced intrusively, will largely be unaffected by ambient conditions. However, the parameters discussed here are important in considering structures built from thin, compound lava flows and should be utilized in studies of Venusian and submarine volcanism.

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parameter	Earth, subaerial	Venus	Earth, seafloor
g' $(m{\cdot}s^{-2})$	9.80, 9.81	8.61, 8.63	6.54
T_a (K)	290	750	280
ρ_a $(kg{\cdot}m^{-3})$	1.2	65	1000
Percent vesicles	30	10	~0
H_2O solubility	0, 0	0.6, 0.6	1.7
c_l $(J{\cdot}kg^{-1}{\cdot}K^{-1})$	840	1080	1200
t_g	13, 68	15(8.1), 58(31)	0.10(0.041)
η_l $(Pa{\cdot}s)$	10^{10}, 200	10^8, 100	70
κ_l $(x10^{-7}\ m^2{\cdot}s^{-1})$	7.5, 6.0	6.7, 5.4	5
ρ_l $(kg{\cdot}m^{-3})$	2220, 2500	2490, 2800	3000
$v_l(m^2{\cdot}s^{-1})$	$4.5x10^6$, 0.080	$4.0x10^4$, 0.036	.023
$H/H_{Earth,\ subaerial\ bas.}$	87, 1.00	27(89), 0.85(1.03)	0.81(1.11)

Values separated by commas are for rhyolite and basalt, respectively. Seafloor values shown for basalt only. Values in parentheses are those assuming subaerial lava properties. *Italics* refer to lava properties that are different due to the ambient environment. g' = specific gravity, T = temperature, c = specific heat, t_g = time to reach the glass transition, η = the dynamic viscosity, κ = the thermal diffusivity, ν = the kinematic viscosity, $H/H_{Earth,\ subaerial\ bas.}$ = the height of a flow relative to the height of a subaerial basalt flow. Subscripts a and l refer to ambient and lava, respectively. These tabulated parameters are for comparative purposes only and are individually non-unique.

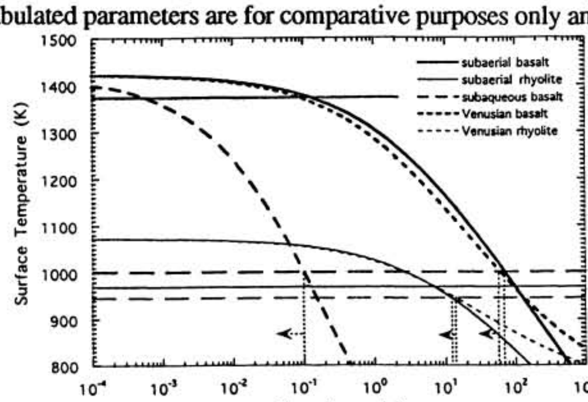

Figure 1: Plot of surface temperature vs. time for basalt and rhyolite lava flows on Venus and Earth (subaerial and subaqueous). Heavy horizontal lines are the solidus (solid) and glass transition (stippled) temperatures for basalt. Light horizontal lines are for rhyolite. Solidification occurs when the temperature reaches the glass transition, marked by vertical dashed lines. Arrows show when solidification would occur assuming subaerial lava properties.