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The role of viscous dissipation and thermal conductivity in explosive and extrusive volcanic eruptions.

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Most models for magma flow in volcanic conduits assume isothermal ascent conditions due to the high heat capacity of the magma. Here for bubbly liquid we present a non-isothermal 2D flow model that accounts for the temperature-dependent viscosity of magma and viscous dissipation of heat. In the case of explosive eruptions the model is combined with 1D equations for gas-particle dispersion flow after magma fragmentation. The boundary value problem of the determination of discharge rate for given conditions in a magma chamber and at a conduit outlet is solved. Significant changes in velocity and temperature profiles result in strong reduction of the conduit friction and, therefore, an order of magnitude increase in discharge rate in comparison with the isothermal case. This allows high intensity eruptions to occur from significantly narrower volcanic conduits and so resolves inconsistencies between conduit dimensions inferred from models and observations. For a given conduit diameter fragmentation can occur at much shallow depths. Existence of viscous dissipation in explosive volcanic flows is proven by the presence of two types of pumices that were erupted simultaneously on Mt. Pinatubo and some other volcanoes. Grey pumice shows signs of significant heating and shear. Extrusive eruptions are characterized by magmas with high crystal content leading to a much higher viscosity. At low discharge rates heating due to the viscous dissipation is small and magma ascent is nearly isothermal. For higher discharge rates the zone of hot magma appears near the conduit walls and significantly reduces the resistance of the conduit. Because of the slow magma ascent the heat spreads into the conduit interior by thermal conductivity, the zone of elevated temperatures is much wider and maximum temperatures are smaller than for the case of explosive eruption. Eruption with much higher discharge rate is possible through the conduit of the same diameter in comparison with 1D isothermal model.