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89.304 - IGNEOUS & METAMORPHIC PETROLOGY
MAGMA CONVECTION, COOLING, AND MIXING

1. A flood basalt is erupted and forms an extensive 50-m-thick lava lake. A 5-m-thick crust develops rapidly due to radiation cooling and water percolating into surface cracks. A 1-m-thick chill zone forms at the base of the lake, but the low thermal diffusivity of the underlying rocks does not allow it to continue thickening rapidly. Following some cooling, the magma in the lake has an average viscosity of 10^3 Pa s, a density of 2700 kg m^{-3}, a thermal diffusivity of 5 x 10^{-7} m^2 s^{-1} and a coefficient of thermal expansion of 5 x 10^{-5} K^{-1}. The surface of the lava lake is kept at the ambient temperature of 25°C, which in turn keeps the base of the crust (top of the magma) at 1065°C. The top of the lower chill zone remains almost constant at 1150°C; heat lost into the underlying rocks is replaced by heat liberated by crystallization.

   a. Assuming that these conditions hold relatively constant for some period of time, will the magma convect? You will need to calculate the Rayleigh number.

   b. If convection does occur, calculate the maximum convective velocity.

   c. Calculate how long it would the lava lake take to crystallize if there is convection, and how long if convection doesn't occur.

2. A basaltic magma at 1200ºC containing 10 wt% phenocrysts commingles with a 900ºC rhyolitic magma containing 10 wt.% cristobalite phenocrysts. The commingled magma consists of 30% basaltic magma and 70% rhyolitic magma. After commingling, all the cristobalite phenocrysts are resorbed, while the percentage of phenocrysts in the basaltic magma increases to 30 wt% (60% pyroxene and 40% plagioclase). If the heat capacities of all phases are taken to be 0.8 kJ kg^{-1} $^oC^{-1}$ and the latent heats of fusion of cristobalite, pyroxene and plagioclase are 135.8, 587 and 490 kJ kg^{-1}, respectively, calculate the final temperature of the commingled magma.