

E&PS 303 - Igneous Homework #3

Please attach a separate page with your answers to **Part I** and **Part IIb**

Part I. The rate of sinking of crystals or xenoliths in a magma can be estimated from Stoke's Law:

$$V = \frac{2gr^2(\rho_s - \rho_l)}{9\eta}$$

where **V** is the terminal velocity of a solid with radius **r** falling through a melt of viscosity η under gravitational acceleration **g** (9.8 m s^{-2}); ρ_s and ρ_l are the densities of the solid and liquid, respectively. (Note that Stoke's Law assumes that the magma is completely liquid, i.e. that there are no crystals already present in it. If any preexisting crystals are present, they will impede the settling of the crystal or xenolith of interest and Stoke's Law calculations will yield only a maximum settling velocity). **Pay careful attention to units in the calculations that follow!!**

(a) Consider a mafic magma of density 2.58 g cm^{-3} and viscosity 3000 poise ($1 \text{ poise} = 1 \text{ g cm}^{-1} \text{ s}^{-1}$). How large would a plagioclase grain ($\rho = 2.68 \text{ g cm}^{-3}$) have to be in order to settle to the bottom of a magma chamber at the **same rate** as an olivine grain ($\rho = 3.70 \text{ g cm}^{-3}$) that has a radius of 1 mm?

(b) In lab, you saw several examples of cumulate rocks in which the cumulate plagioclase grains were significantly larger than the cumulate olivine grains. How might you explain this observation?

(c) Consider the case of a dunite xenolith with a radius of 20 cm that is erupted in an alkali basalt on Hawaii ($\rho_{\text{xen}} = 3.45 \text{ g cm}^{-3}$; $\rho_l = 2.80 \text{ g cm}^{-3}$; $\eta = 2000 \text{ poise}$). What was the minimum ascent rate of the alkali basalt, in **km/hr**? What is the maximum amount of time that it would have taken for the xenolith take to rise from 100 km depth to the surface, in **days**?

(d) When Krakatoa erupted in 1883, it sent pumice fragments flying out over the ocean. If the pumice pieces had an average radius of 4 cm and a density of 0.95 g cm^{-3} , how long would it have taken for them to sink 5000 m to the ocean floor ($\rho_{\text{seawater}} = 1 \text{ g cm}^{-3}$). Speculate on what the ultimate fate of the pumice might have been. There is a reason that I have not given you the viscosity of seawater. (Remind me to tell you what *actually* happened to the pumice erupted from Krakatoa).

Part II.

(a) Settling of crystals from a tholeiitic melt can produce substantial changes in the chemistry of the residual melt. Using the chemical analyses in the accompanying table, calculate the composition of the magma residue left behind after *simultaneous fractional crystallization* (removal) of 10% olivine ($\sim \text{Fo}_{82}$), 20% plagioclase ($\sim \text{An}_{75}$), and 10% augite ($\sim \text{Wo}_{40}\text{En}_{50}\text{Fs}_{10}$) from the basaltic parental melt. **Be sure to normalize your answer so that the weight percent oxides sum to 100.0%.**

(b) We will be talking in lecture about magma differentiation along "tholeiitic" vs. "calcalkaline" trends; the former is characterized by a dramatic increase in FeO content with increasing SiO_2 during differentiation, whereas the latter shows no such iron enrichment. Does the fractional crystallization history you determined in (a) take the remaining melt on a tholeiitic or a calcalkaline trend? Hint: look at the FeO/MgO ratio for the parental melt in comparison to the residual melt.

Compositional data and worksheet for **part II**:

	parental basalt	Olivine	Ol x 0.1	Plag	Plag x 0.2	Augite	Cpx x 0.1	(Basalt – Crystals)	Residual melt
SiO ₂	51.24	40.0		50.0		52.0			
TiO ₂	0.83	0.0		0.0		0.0			
Al ₂ O ₃	17.08	0.0		32.0		0.0			
FeO	9.64	17.0		0.0		7.0			
MgO	6.27	43.0		0.0		18.0			
MnO	0.18	0.0		0.0		0.0			
CaO	11.50	0.0		16.0		23.0			
Na ₂ O	2.57	0.0		2.0		0.0			
K ₂ O	0.55	0.0		0.0		0.0			
P ₂ O ₅	0.14	0.0		0.0		0.0			
total	100.0	100.0		100.0		100.0			100.0

Note: Each cell in “Basalt – Crystals” column = “parental basalt” – (Ol x 0.1) – (Plag x 0.2) – (Cpx x 0.1).

Each cell in “Residual melt” = cell in “Basalt – Crystals” column x (100/sum of “basalt – crystals”)