Seminar 7 (to follow Lecture 10)

"Trace element and isotopic effects of combined wallrock assimilation and fractional crystallization" by DePaolo, EPSL, 53, 189-202, 1981

For more recent contributions that incorporate energy balance constraints see "Energy – constrained open-system processes I and II" by Spera and Bohrson, Jour. Petrol., 42, 994-1018 and 1014-1041, 2001.

A magma composition is initially determined by the composition of its source and the partial melting process; however, as a magma ascends and cools, processes such as fractional crystallization and assimilation of wallrocks are expected. The DePaolo paper recognizes that these two processes are likely to be coupled; i.e. when a magma crystallizes, the accompanying latent heat of crystallization can be used to heat and partially melt the wallrock.

Figure 2 of this paper compares the TE abundance of the initial magma as a function of F (the mass fraction of melt) for both fractional crystallization and combined fractional crystallization and assimilation. For the example shown, the rate of assimilation is 20% of the crystallization rate (both in units of mass/time). We see that the abundance of an incompatible element is very sensitive to the concentration in the assimilant (either as a bulk- wallrock or a partial melt of the wallrock). If Ca/C_o^m is >1 the melt is more enriched than the 1/F limit of fractional crystallization. In contrast, perhaps non-intuitively, the abundance of a compatible element in the crystallizing assemblage reaches a steady state at low F.

Figure 4 shows how the trajectory for simple two component mixing is complicated as a result of combined fractional crystallization and assimilation. (For important background on mixing see the paper "General mixing equation with applications to Icelandic basalt" by Langmuir et al., EPSL, 37, 386-392, 1978). In particular, the pathway for combined fractional crystallization and assimilation are very sensitive to the relative TE concentration in the fractionating phases (e.g., olivine followed by olivine and plagioclase) to that in the assimilant.