Planetary Geology 4460
Homework #5 Solution
Due Fri. Oct. 6, 2017

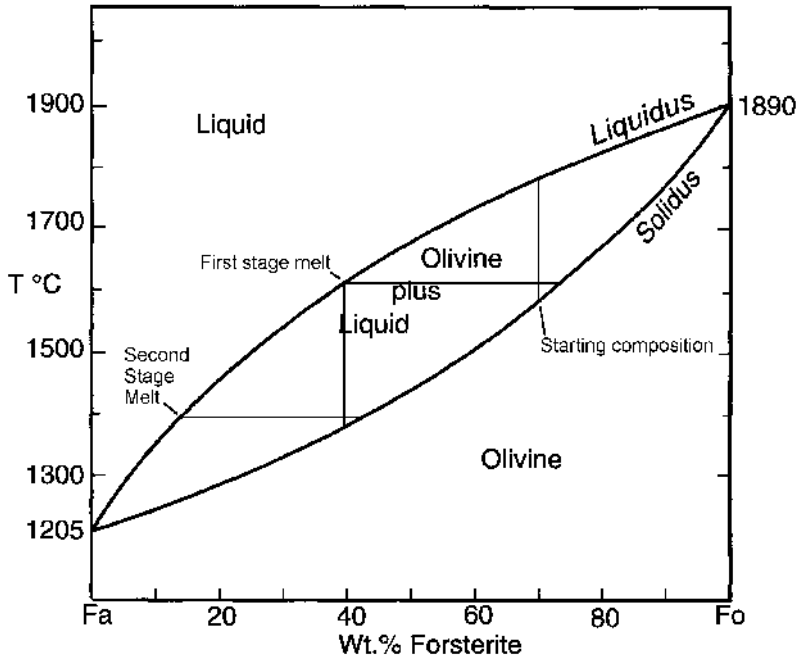
1) Multi-step partial melting. (30 points)

Part A. Suppose you start with "mantle" olivine with a composition of 70% Forsterite, 30% Fayalite. You let it melt till 10% is liquid, then that magma escapes to form surface basalt, or a near surface intrusion. What will be the composition of that basalt? (Hint: Use the lever rule.)

Since we have 10% melt and 90% solid we need to find a place on the phase diagram where the distance of the melt composition from the original is 9 times the distance of the solid composition from the original. By eye on the original question printout the distance between the melt and the solid composition at roughly this location is about 35 mm. So the distance of the solid composition (from the original 70% value) will be roughly 3.5 mm and the distance of the liquid composition (from the original 70% value) will be roughly 31.5 mm. This occurs at T ~ 1609^{O}C, melt composition ~ 39.5% forsterite (and solid composition about 73.3% forsterite). As a sanity check, 70%-39.5%=30.5%, and 73.3%-70% = 3.3%. To the level of accuracy we've measured (roughly 0.5% composition) 30.5/3.3 = 9.2, which is approximately equal to the 9 we want.

Part B. At some later time that near surface basalt is reheated (either by new magma from below, or by subduction) and begins to melt. Once again this continues until 10% is liquid, then that magma escapes to form a new intrusion or flow. What is the composition of that new material. (Again remember the lever rule.)

Using 39.5% as a starting composition, and repeating the above work, we get a second-melt composition of approximately 13.7% by weight forsterite, at a temperature of 1393^{O}C.



Part C. Suppose you find some way to determine the amount of residual solid left from the Part B (second stage) melting. This could be via seismic techniques or mapping of deposits after they have been uplifted and eroded. How much residual solid should you expect to see for every kg. of Part B solidified magma? (This is a very easy question – intended mostly as a hint on how to get started towards answering Part D.)

Since the melt fraction was 10% there must be 9 kg. Of solid left for every 1 kg of melt you generated.

Part D. How much total mantle material (both residual solid and escaped stage one (Part A) melt must be processed to produce every kg. of the final second stage (Part B) magma?

In this version we want the total amount of material processed – not just the residual solid. If we process 100 kg of material in stage A we get 10 kg of melt, then if we process that again in stage B we get 1 kg of melt. So the answer is 100 kg: 10 times 10.

Note – In a real-world situation the composition of the original material will be more complex as will the composition of the resulting melts. However this basic process is the way you can create silicic magma beginning with much more mafic mantle material.