Arc Volcanoes - A case study of Mt. Doom

On our fieldtrip the other day, you witnessed physical evidence for processes such as magma-mixing and assimilation, and fractional crystallization was discussed (if you need a refresher on what these processes are, do some reading). The importance of these processes in magma genesis and evolution beneath volcanic arcs cannot be stressed enough. As an illustration, I give you real samples from a continental setting and place them into a fictitious setting for your enjoyment. Welcome to Mt. Doom - a typical calc-alkaline volcano ("raining down doom since 2003").

Figure 1 is a figurative cross-section through Mt. Doom, vaguely illustrating the growth-history of the volcano as a series of volcanic eruptions of various compositions. Blown-up to the right of the volcano is stratigraphic-section A, which is composed of six lava flows which all erupted from the same vent (i.e. each flow came from the same hole). The goal of this lab is to examine the macroscopic, microscopic and geochemical characteristics of these rocks so that you can better understand the magmatic processes occurring at depth. Undoubtedly, the progressive evolution of these lava flows will somehow involve fractional crystallization, assimilation and magma-mixing, but our goal is to figure out whether or not we can discern which processes are dominating over the course of these eruptions.

1. The normal way to investigate a series of rocks of known stratigraphic relation is from the bottom up - oldest to youngest. We will do the same here. Examine both the hand sample and thin section for 79-35d, 79-33b and 79-8a.

a. For each of these, do the following: Identify the phenocrysts, and estimate their abundances (and I mean *estimate*). Keep this in the back of your mind: which phases were on the liquidus at the time of eruption? Make sure that you are convinced that each of the phases you identify are in equilibrium with the magma - if they are not, make a note of it.

b. Now look at table 1 and examine the geochemical composition of these rocks. Based on the mineralogy you saw in thin section and the major-element chemistry, give each of the rocks a name (if you don't know how to name a rock based on its geochemistry, read about it).

c. Examine the chemical composition of these rocks in more depth. Compare the abundances of each of the major elements in each of the rocks to one another. Are there any striking trends in the geochemistry as you move up stratigraphically (pay particular attention to MgO, CaO, and Al_2O_3)?

d. Using what you saw in thin-section, and taking the geochemistry into account, what is the simplest explanation for the relationship of these three magmas? Explain your answer.

2. Now that we have that figured out, we can move upwards. Examine the hand sample and thin section for sample 79-26.

a. Again, identify the phenocrysts, estimate their abundances and using the information in table 2, name the rock. Are all the phenocrysts in equilibrium with the magma?

b. Pay particular attention to the plagioclase in this sample - yes, many of them show wonderful zoning. Figure 6.1 at the back of this handout has the Ab-An phase diagram, which you are all familiar with. Use this diagram and table 2 to explain the observed zoning. Is this story consistent with the one you came up with for the lava flows stratigraphically below? In what ways is it, and in what ways isn't it?

3. There is additional information that we can retrieve from this lava flow. Samples 97-8 and -9 were collected as enclaves within this flow. An enclave is essentially a cognate xenolith, but the implication is that it coexisted as a magma at the same time as its host rock. In other words, the enclave is an immiscible liquid within the host magma. These particular enclaves are somewhat misleading, because they are coarse-grained, perhaps implying that they are simply xenoliths. However, their rims exhibit quenched texture, showing that they were at least partially-molten when they became included in the magma represented by 79-26.

a. How do you think that these enclaves ended up in the magma represented by sample 79-26?

b. Identify the phenocrysts present in the enclaves (don't bother estimating their percentages). What does their texture tell you about their history?

c. Using the mineralogy and table 2, give 97-8 and 97-9 names.

d. Finally, does the presence of these enclaves help explain the textures and the geochemistry of sample 79-26? Why and/or why not?

4. I think you get the picture - I have asked enough leading questions. For the next three samples, conduct similar tests by looking at their thin-sections, the geochemistry, and their stratigraphic relationships. You decide what the interesting information is and tell it to me (this is what geology is - using tools to distil lots of information into bite-size stories). You should be able to sum it up in a couple of paragraphs with any lists or sketches you deem necessary.

5. The final step in any igneous petrology paper which tries to explain magma-chamber processes is to draw little box diagrams with magma-chambers and dikes and little crystals leading to other magma-chambers, and eventually with a dike leading to the bottom of a smoking volcano. Now you should do that (this is your reward for having done all that work). The basic idea is to take the relative-timing of the processes you described above and drawing sketches that make the information easier to understand. It should also give us some physical sense of what is happening beneath Mt. Doom. Attached to the back of this handout are some examples from some of Tim's papers and one from Bair's senior thesis. The biggest mistake people make is over-interpreting what they actually have evidence for.