EESC 4701: Igneous and Metamorphic Petrology

MAGMA PLUMBING SYSTEMS

LAB 7

Due April 12

NAME:

Purpose: *In this lab you are going to use bulk rock and melt inclusion data to understand that transport and evolution of magmas.*

Outline

- Read prompt
- Plot sample locations in Google Earth
- Perform geothermometry and geobarometry on melt inclusion samples
- Model magma evolution using PELE
- Make a series of Harker diagrams
- Create two data tables
- Answer the questions in the lab (type your responses)
    - In the same document, add in all of your figures and tables

Prompt

You want to know about magma ascent and evolution at Shishaldin volcano. So, you go out and collect lavas that have erupted from the main vent and tephra erupted from cinder cones on the volcano's flank. You study the different samples because you believe that all the magmas erupted at this volcano have the same initial (parental) composition and undergo similar differentiation processes but the magmas can be erupted at different stages of differentiation. In other words, you believe all of the samples from this volcano (melt inclusions and bulk rocks) belong to a single liquid line of descent.

Bulk rock samples

You have all your samples and their coordinates, but now that you're back in the office, you'd like to review your sample sites. To do so, use the sample location spreadsheet and plot the locations using the following website:

https://www.earthpoint.us/ExcelToKml.aspx

Take a screen shot of your Google Earth map. Make sure that it includes a compass and a scale.

Now, call up the bulk rock data in excel and have a look at it. To do so, normalize the data to 100% and plot it as two different data series on a set of Harker diagrams. One data series should include all of the samples from the main vent, and the other data series should be the samples from the cinder cones (a.k.a. side cones, parasitic cones, monogenetic vents, scoria cones, etc.). Below is a brief description of each of your samples.

Note that each tephra sample that you have bulk rock data for below also has melt inclusion data (that you will look at in the next section of the lab). Additionally, you have looked at the minerals from each sample closely, and all of the minerals appear to be chemically zoned.

DJR15SH01 – Tephra; cinder cone; contains olivine and spinel

DJR15SH02 – Tephra; cinder cone; contains olivine and spinel

DJR15SH03 – Tephra; cinder cone; contains olivine and spinel

DJR15SH04 – Tephra; cinder cone; contains olivine, spinel, clinopyroxene, plagioclase

DJR15SH05 – Tephra; main vent; contains olivine, spinel, clinopyroxene, plagioclase, apatite

DJR15SH06 – Lava; main vent; contains olivine, spinel, clinopyroxene, plagioclase

DJR15SH07 – Tephra; main vent; contains olivine, spinel, clinopyroxene, plagioclase

DJR15SH08 – Lava; main vent; contains olivine, spinel, clinopyroxene, plagioclase

DJR15SH09 – Lava; cinder cone; contains spinel

DJR15SH10 – Lava; main vent; contains olivine, spinel, clinopyroxene, plagioclase

Questions:

1. Compare the chemistry of the eruptive products from the main vent and the cinder cones.

2. What sample is the most primitive?

Melt inclusion samples

Now have a look at the melt inclusion data. To do so, plot the melt inclusion data on the Harker diagrams you have already constructed. In order to do this, you must normalize your melt inclusions to volatile-free compositions (in other words, ignore the H_2O and CO_2 contents of your melt inclusions and normalize the rest of the composition to 100%).

Questions:

3. Is there any systematic difference between the composition of the melt inclusions and that of the bulk rock that is associated with the same sample?

4. How does the composition of the melt inclusions relate to the bulk composition of the host tephra? Comment.

Geothermometry

Equilibrium between a particular mineral and melt happens at a specific temperature. So, if you know the composition of a melt (e.g., melt inclusion composition) and you know that it was in equilibrium with a certain mineral (which is assumed for melt inclusions because the mineral hosting the melt inclusion grew from the melt that was entrapped to form the melt inclusion).

To model the temperatures of entrapment of the melt inclusions, use the modified version of the Helz and Thornber (1987) thermometer presented by Putirka (2008), found below. This thermometer works for melt that is in equilibrium with olivine. Since all of your melt inclusions are hosted in olivine, it should work. For our purposes, we will assume that the thermometer has an error of +/- 50°C.

$$T(^\circ\mathrm{C}) = 26.3\mathrm{MgO}^{liq} + 994.4\ ^\circ\mathrm{C}$$

<u>NOTE:</u> The thermometer you are using is only calibrated to mafic samples. It will produce decent results except for with sample DJR15SH05, which is okay because in this sample you've used a different geothermometer and have determined that the melt inclusions were all entrapped at 880°C.

<u>Questions</u>

5. What is the range of entrapment temperatures?

6. Are the least evolved melt inclusions entrapped at higher or lower temperature?

7. What is one major flaw with the thermometer we are using (other than its limited range of calibration)?

Barometry

The amount of volatiles that can be dissolved in a magma is limited by pressure. Thus, the volatile contents of melt inclusions can tell us about the pressure of melt inclusion entrapment. Volatile solubility also depends on melt composition and temperature. Fortunately for our melt inclusions, we know these two things!

Use the VolatileCalc spreadsheet to calculate vapor saturation pressures for your melt inclusions. Use the basalt option (assume all melt inclusions have 49 wt.% SiO_2) for all samples except DJR15SH05. Use the rhyolite option for this sample. Convert the vapor saturation pressure into a depth of entrapment assuming the overlying rock has a density of 2.7 kg/m^3.

Make a plot of melt inclusion MgO content (x-axis) versus entrapment depth (y-axis).

<u>Questions</u>

8. What important information is not included in the vapor saturation pressure calculation (*hint* what assumption did you make?)?

9. What range of depths were your melt inclusions entrapped at?

10. Is there a particular depth (or a limited range of depths) over which a large number of your melt inclusions are entrapped? What might you infer exists at that depth?

PELE modeling

Take what you know about how magmas evolve during ascent and model the melt evolution. To do this, consider the following suggestions:

- You can use your most primitive bulk rock composition as the parental melt composition
- Melt inclusion entrapment pressures tell you about the stage of magmatic differentiation at a particular depth
- Your data are probably going to be best fit by a two stage model
    - In the first stage, magma undergoes polybaric fractionation
    - In the second stage, magma undergoes isobaric fractionation
- Assume the system is reducing, and the most appropriate oxygen fugacity buffer is QFM-1

After you have completed your modeling, plot the results on your Harker diagrams.

<u>Questions</u>

11. Does your model fit your data well? Why or why not?

Make a cross section of the magma plumbing system

Now you will combine all of your observations and make a model of the magma plumbing system at Shishaldin. To do so, draw a cross section of the volcano, which should include labels and indicate depths where appropriate. You can draw this either electronically or by hand. Consider the following:

- Is there a magma chamber? Where is it located?
- Is magma feeding the cider cones originating from the same location as the magma feeding the main vent?

Make tables

Add the results of your geothermometry and geobarometry to the excel sheet. Label the tables as Table 1 and Table 2 and give each a name.

Respond to questions

Type responses to all of the questions using Word. Use full sentences to respond.

Compile figures and tables

Compile the figures that you have made into the same Word document as your question responses. Label them Figure 1, Figure 2, etc. Give them a title (e.g., "Harker diagrams of bulk rocks, melt inclusions, and PELE model results"). The figures should include:

- Sample map
- Harker diagrams that include:
  - Bulk rock data
  - Melt inclusion data
  - PELE model results
- MgO vs. entrapment pressure figure for melt inclusions
- Drawing of the magma plumbing system
- Any other plots that you find interesting

Compile your two tables (bulk rock data and melt inclusion data), and add these to the Word document.

You may print the lab and submit it next class or you can email the lab to me. <u>If you email, you must submit everything as a single Word document or PDF.</u>