EOS 240: Lab Assignment 2

Major, minor, and trace elements in Earth's mantle

Due: 2:30 pm January 29, 2026 (Th section)
Due: 1:30 pm January 30, 2026 (F section)

You have one week to complete this assignment. You should submit your response to the course Brightspace page as a single PDF file. **Additionally, we ask that you upload a copy of the scripts, code, or spreadsheets you used to complete the assignment. These documents will help us track down mistakes.** Responses to questions should be typed, using complete sentences and standard grammar. If you choose to support your answers with hand-drawn illustrations or hand-written calculations, you should scan or photograph the written work and integrate it into your PDF file as a figure. Double check that your image resolution is high enough to read. A google search of 'PDF combiner' will return a number of webpages that allow you to upload individual images and combine them into a single .pdf file (example: combinepdf.com). There are also a number of good apps for mobile phones. If you write your response in a word processor, please export to .PDF before submitting your response.

You are not excluded from working with others (pairs are recommended), but each person will submit their own copy of the assignment. In your submission, include the names of anyone you worked with on the assignment.

To answer the questions, you can perform calculations and make figures using Excel (an open source alternative: www.libreoffice.com), or with a program or programming language of choice.

Name : ______________________________

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Marks:	4	9	11	24
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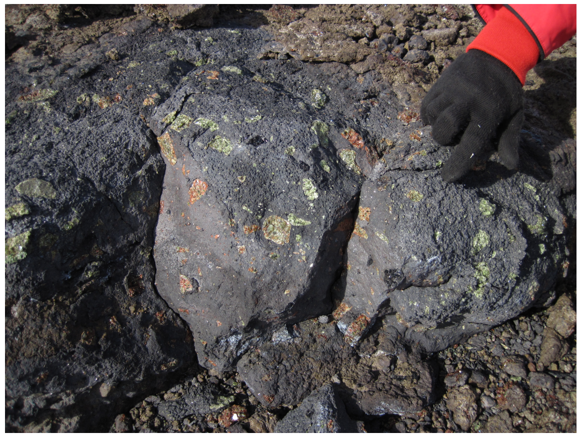

Figure 1: A basalt (dark) hosting a number of peridotite xenoliths (green). These xenoliths are carried up to the surface from the upper mantle and provide some direct insight into the chemistry and mineralogy of the mantle.

Introduction

In this lab, you will use peridotites and chondritic meteorites to build a geochemical model of Earth's upper mantle. In the first question, you will compare variations in Mg, Al, and Si in Lherzolite xenoliths to variations in chondritic meteorites to determine a subset of xenoliths that may represent pristine (unmelted) upper mantle. In question 2, you will compare the average composition of this subset of samples to the volatile rich CI chondrites. To explain some of the chemical differences you will find between Earth's mantle and CI chondrites, you will rely on your understanding of the Goldschmidt element classification scheme and element condensation temperatures.

Question 1 (13)

Determining the chemical composition of the upper mantle

(a) (1 point) Last week we saw that the % forsterite content in Harzburgites (little to no clinopyroxene) was higher than the % forsterite content in Lherzolites. Which type of peridotite should be more representative of unmelted mantle and why?

(b) (2 points) You have been provided a data table that contains whole rock geochemical measurements of peridotite xenoliths (*peridotites.csv*). Xenoliths are fragments of rock that get entrained and transported by magmas. These xenoliths are some of the most pristine mantle rocks we have discovered, and have been selected by their mineral assemblages and chemistry. However, there still exists some variation in their major element chemistry. Moreover, the major element chemistry of these samples does not overlap with any of the chondritic meteorites. For the peridotite data, make a scatter-plot that shows the ratio of Al to Si (Al/Si) on the x-axis and the ratio of Mg to Si (Mg/Si) on the y-axis.

(c) (1 point) Explain the chemical variability in this diagram in terms of a process. Annotate your figure with an arrow that represents this process and the direction it proceeds.

(d) (1 point) Let us assume that this process can be represented by a line. Fit a line through the peridotite data and plot it on your figure. Write down your linear function in the form $y = mx + b$ where m is your slope and b is your y-intercept. We can refer to this line as a *chemical fractionation line*, where a process or set of processes are inferred to cause chemical variation that follows this line.

(e) (2 points) You have been provided a data table (*wasson_chondrites.csv*) that contains whole rock geochemical measurements of chondritic meteorites. The major element and refractory element composition of these undifferentiated meteorites is very similar to the sun, and the simplest model for planet formation calls for the bulk composition of the terrestrial planets to be chondritic. Add the chondritic data to your scatter plot from part (a). Show the ratio of Al to Si (Al/Si) on the x-axis and the ratio of Mg to Si (Mg/Si) on the y-axis.

(f) (2 points) Magnesium, Silica, and Aluminum are refractory lithophile elements (RLE). We have discussed that it a safe assumption that the RLE content of the bulk earth and solar nebula should be the same. Provide an explanation for the fact that the peridotite data and chondrite meteorite data in your figure do not perfectly match?

(g) (1 point) If all chondrites perfectly represented the solar nebula, their whole-rock chemistry would not vary. The variations represent the sum of chemical reactions experienced by these meteorites since formation. Define this set of reactions as a line through the chondrite data (this line is referred to as the *cosmochemical fractionation line*). Fit a line through the meteorite data and plot it on your figure. Write down your linear function in the form $y = mx + b$ where m is your slope and b is your y-intercept.

(h) (1 point) If your two *fractionation* lines represent processes that have altered our sample, what does the intersection of the two lines represent?

(i) (1 point) Your system of two linear functions are solved at the intersection of the two lines. What is the Mg/Si and Al/Si composition at the intersection (show and/or describe your steps).

(j) (1 point) Find the 10 peridotite samples that are closest to the composition at the intersection. For each sample, calculate the difference in the Al/Si ratio of the sample and Al/Si ratio of the intersection of the two fractionation lines. Let us call this value x_{diff}. Now calculate the difference in the Mg/Si ratio of each sample and the Mg/Si ratio of the intersection of the two fractionation lines. Let us call this value y_{diff}. We can use the Pythagorean theorem to calculate the distance (in our x-y grid) between each sample and the intersection:

$$R = (x_{diff}^2 + y_{diff}^2)^{\frac{1}{2}}$$

The 10 smallest R values should correspond to the 10 closest peridotite samples. From this subset of 10 samples, calculate the average composition for each of the provided chemical measurements. (A blank value means that the measurement was not performed, not that concentration of that element is zero). These average values are an excellent starting point for estimating the chemical composition of Earth's upper mantle. Provide a table of your upper mantle geochemical model.

Question 2 (11)

Comparing your upper mantle composition to CI chondrites

The CI chondrites are the least altered of the meteorites. **C** stands for carbonaceous and **I** stands for Ivuna, the type locality in Tanzania. You will now *normalize* your model mantle chemical composition to the Si content of CI chondrites.

(a) (1 point) Determine the value that you must multiply your upper mantle silica content by to make it equal to the silica content in the CI chondrites. Multiply each chemical component of your mantle model by this silica-normalizing factor. Provide a table of this Si-normalized model.

(b) (2 points) Make a figure that shows the relative abundance of elements in your Si-normalized mantle model as compared to CI chondrites. In other words, divide each chemical component of your Si-normalized mantle model by the corresponding component in the CI chondrite data. *Be sure to check the units on the chondrite datasheet, some of the units will need to be converted to compare the mantle (μg per g) data to the chondrite data.* The x-axis should be populated with the elements, and the y-axis should be the abundance of that element in your mantle model divided by the chondritic abundance. For the next questions, it may help to display your y-axis on a log-scale.

Your figure now shows the relative composition of the upper mantle when compared to CI chondrites. Elements with values that lie above 1 are enriched in the upper mantle when compared to CI chondrites and elements with values that lie below 1 are depleted in the upper mantle when compared to CI chondrites. We have discussed at least two ways to fractionate elements in our solar system: the temperature of condensation (refractory vs volatile) and the affinity of an element towards silicate (lithophile) or iron (siderophile) melts. You have been provided a table of elemental condensation, T_c, and a periodic table with the Goldschmidt classification of each element. Use these resources to answer the following questions about the chemistry of your upper mantle model.

(c) (2 points) Does the upper mantle have more or less Fluorine than CI chondrites? Why?

(d) (2 points) Does the upper mantle have more or less Cobalt than CI chondrites? Why?

(e) (1 point) Look at the Lanthanides (La to Lu). If you plot each relative abundance in atomic number order, you should see a general trend to their abundances in the mantle. Describe this trend.

(f) (3 points) Can you predict this trend using condensation temperatures or the Goldschmidt classification of elements? Support your response (Yes or No) with specific examples.