Homework 3

ESTIMATING POTENTIAL TEMPERATURE BENEATH MID-OCEAN RIDGES

1. Refer to the (Putirka, 2005) paper.
    a. Explain what K_D(Fe/Mg) and k_d(Fe) and k_d(Mg) are. Show how K_D is related to k_d.
    b. Make a plot of Mg# (molar Mg/(Mg+Fe)x100) versus Forsterite content in olivine for different K_Ds (between 0.2 to 0.5). If the olivine in the upper mantle is typified by Fo89 olivine compositions, what is the Mg# of a melt in equilibrium with the upper mantle?
    c. Why is k_d temperature dependent but K_D less so?
    d. Reconstruct for yourself a plot equivalent to Figure 3 for K_D=0.32
    e. Explain or show how one might use the figure you produced in *d* to estimate the temperature of a magma.

2. Go to Ridge PetDB (http://www.petdb.org/index.jsp), which is a database of mid-ocean ridge basalts. Download whole-rock major and trace-element data for a suite of basalts from some ridge segment. Make sure to specify which ridge segment your data are from (e.g., latitude and longitude intervals). Denote whether you are using whole-rock or glass data or both.
    a. Plot "Harker" variation diagrams, e.g. plot CaO, SiO_2, Al_2O_3, MnO, FeO, TiO_2, Na_2O, Ni, and Mg# (molar Mg/(Mg+Fe)x100) versus MgO content.
    b. Describe the trends you see in a) and give your best explanation for these differentiation trends. Be specific on what minerals are likely to be crystallizing.
    c. What is the highest Mg# of the basalts in your dataset? Using your result in 1b, what is the forsterite content of the olivine that would be in equilibrium with such a magma? Compare this forsterite content with that you would expect olivine in the upper mantle to have.
    d. Calculate the cation fraction of Mg and Fe in your lava samples. Plot them on a plot of XMg versus XMg, e.g. your plot in question 1d. Using Putirka's refined thermometer (1d), estimate what the temperature of your most magnesian magma is.
    e. Assuming that our magma originally came from a mantle having a Forsterite content of 89-90 and its FeO content has not changed much because our magmas have followed an olivine differentiation path, estimate the temperature of the primary magma.

3. Potential temperature
    a. Define what potential temperature means.
    b. Assume that the depth of last equilibration of your primary MORB magma is equivalent to a pressure of ~1.5 to 2 GPa (what depth does this correspond to?). On a T-P plot, denote the dry lherzolite solidus and liquidus (use the parameterizations shown in (Katz et al., 2003) and

(Hirschmann, 2000). Denote as a point the temperature and pressure of last equilibration for the primary MORB magma.

c. Using the approach in Putirka (2005), estimate the melting adiabat path and its intersection with the dry solidus. Then calculate the potential temperature of the magma by extrapolating the point of intersection upwards to the surface along a solid adiabat. Show your work.

Hirschmann M. M. (2000) Mantle solidus: experimental constraints and the effects of peridotite composition. *Geochem. Geophys. Geosys.* **1**, 2000GC000070.

Katz R. F., Spiegelman M., and Langmuir C. H. (2003) A new parameterization of hydrous mantle melting. *Geochem. Geophys. Geosys.* **4**, doi:10.1029/2002GC000433.

Putirka K. D. (2005) Mantle potential temperatures at Hawaii, Iceland, and the mid-ocean ridge system, as inferred from olivine phenocrysts: evidence for thermally driven mantle plumes. *Geochem. Geophys. Geosys.* **6**, doi:10.1029/2005GC000915.