

Decompression melting and igneous processes

This homework is designed to help you work through the principles of adiabatic processes, melting and igneous differentiation discussed in lecture, and practice graphical calculations based on the 'lever rule'. The problem set focuses on an idealized representation of the chemical system Olivine-Pyroxene. Please keep in mind that these diagrams are sort of cartoon versions of the behaviors of natural rocks and melts — they contain just enough to let us talk about natural systems, but are wrong in detail.

Figure 1 illustrates a portion of the low-pressure (1 bar) T-X ('temperature-composition') diagram for the olivine-pyroxene system. We will use this diagram to answer questions about the thermal structure and chemistry of an imaginary Earth whose chemistry and mineralogy is fully represented in this simple chemical system. Assume the following things for the purposes of this problem set:

- The lithosphere (cold, rigid 'lid') is 100 km thick.
- All melting in the mantle happens because of adiabatic upwelling of solid rocks in the asthenosphere (hot, ductile part of the mantle under the lithosphere) until their paths in Pressure vs. Temperature space intersect the lines defining their melting reactions in that space.
- Asthenospheric upwelling always stops its vertical motion if it runs into the base of the lithosphere.
- All melting reactions have Clapeyron slopes of exactly 5 km/ °C and all adiabats for rocks and magmas have slopes of exactly 10 km/ °C. If you wish to convert back and forth between pressure and depth, assume 3 km corresponds to 1000 bars (1 kb) of pressure.
- The volcanic lavas erupted on our imaginary world all have chemical compositions that correspond to **55 %** pyroxene component and **45 wt. %** olivine component. Assume that this is the composition of melt when it accumulates at the base of the lithosphere (i.e., at 100 km depth).

PROBLEMS

Questions that require graphical or calculated solutions are in bold; those requiring written, qualitative responses are in normal font.

- 1 What mineral or minerals are present in the asthenosphere of our imaginary world?
Hint: melting of the asthenosphere must be capable of generating the observed melts that come to the surface.
- 2 **Draw a Temperature (horizontal axis) vs. Depth (vertical axis) diagram that contains the solidus for the asthenosphere, projected from the surface to a depth of 1000 km. Add a labeled horizontal line indicating the depth of the lithosphere/asthenosphere boundary (i.e., at 100 km depth).** *Hint: Use Figure 1 to find the solidus at 1 bar pressure, and project it to higher pressures/greater depths using the clapeyron slope.*
- 3 **Using the known composition of basalts on our imaginary earth, the liquidus curves in Figure 1, and the assumed clapeyron slopes for all melting reactions, plot the possible liquidus temperatures of these basalts in Depth vs. Temperature space.** *Hint: the liquidus temperature increases with pressure along a clapeyron slope like that followed by single-component melting reactions.*
- 4 **Assuming that the bulk composition of the mantle on the imaginary world is independently known to contain 34 % pyroxene component and 66 % olivine component, use the lever rule to determine the percentage of melting required to produce the observed composition of erupted lavas.**
- 5 **Draw the adiabat for the mantle of our imaginary world, based on your knowledge of its extent of melting.** *Hint: recall that the basalts are assumed to last equilibrate with the asthenosphere at the base of the lithosphere (100 km depth).*
- 6 Would the asthenosphere of this world melt more or less if the lithosphere were thinned to 10 km, but its adiabat and all clapeyron slopes remained the same? Explain your answer.
- 7 Describe, in qualitative terms, the difference in chemical composition you would expect between lavas generated beneath thick (100 km) vs. thin (10 km) lithosphere.
- 8 **How thick would the lithosphere need to be on our imaginary world have to be in order for its mantle to *never* melt during upwelling?** *Hint: this would occur if the adiabat did not cross the solidus.*

Homework 2

Figure 1

