ESS103A Name_____
Igneous Petrology, Spring 2006 **Due: June 9, 2006**

Homework 6
TERNARY PHASE DIAGRAMS / ISOTOPE CHEMISTRY OF THE COLUMBIA RIVER BASALTS

1. Ternary Phase Diagrams

Finish questions 10-15 on the Di-An-Fo ternary diagram worksheet we partially completed in class on Friday, May 26. Turn these questions in with this homework.

10. ~1320-1325°C. Liquid1 -> An + Fo + Liquid2. F = 1 only need T to describe state of system.
11. $Fo_{16}An_{54}Di_{30}$
12. liquid = 28.6% Fo = 63.3% An = 8.1%
13. instantaneous: $An_{70}Fo_{30}$ cumulative: $An_{11.3}Fo_{88.7}$
14. F = 0 L=> Di + An +Fo
15. composition M – always at eutectic.

2. Rb-Sr and Sm-Nd isotopic systematics

Read p. 277-281 of Winter to learn about the geologic environment of continental flood basalts, and the tectonic setting of the Columbia River Basalts. This should help you understand the geology-related question in this section.

A) Using the partition coefficients (D) in Table 9-1 on p. 157 in Winter, determine the bulk partition coefficients for Sm and Nd in a garnet lherzolite with 60 wt% olivine, 15% opx, 15% cpx, and 10% garnet. Sm: 0.089 Nd: 0.045

B) Is Sm incompatible or compatible in garnet lherzolite? Is Nd incompatible or compatible in garnet lherzolite? Which one is the most compatible in garnet lherzolite? Both are incompatible, but Nd is a little bit more incompatible (Sm is more compatible in gnt lherzolite).

C) Write down the relevant radiogenic decay equations for the Sm-Nd system and the Rb-Sr system (see p. 175). Which is more incompatible, Rb or Sr (we did this in a class handout…)? Describe the difference between the Sm-Nd system and the Rb-Sr system in terms of the relative incompatibility of parent and daughter isotopes. Rb is more incompatible. Just to understand that Rb (parent) goes into the melt for Rb-Sr, but Nd (daughter) goes into the melt for Sm-Nd.

D) Now assume the mantle source material produces a small amount of partial melt. Describe what will happen to the $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ ratios of both the partial melt (and rocks derived from multiple episodes of partial melting) and the depleted source material over long periods of time as radioactive decay progresses. So, $^{87}Sr/^{86}Sr$ is higher in partial melt compared to depleted source, but $^{143}Nd/^{144}Nd$ is lower in partial melt compared to depleted source.

E) Keeping in mind your answer to part D), match the following components to their numbered positions in the isotope diagram of Figure 1. Components 3 and 4 are located off the diagram in the general directions shown.

Bulk silicate earth/enriched mantle 2
Old lower continental crust 3 – switched on original key
Young upper crustal granites 4 – switched on original key

Depleted mantle 1

Hint: very old rocks have had more time to grow in ^{143}Nd, and Sm-Nd isotope systematics are not as easily reset as Rb-Sr.

F) The eruptive sequence of the Columbia River Basalts is given in Table 15-2, and the extrusion rate vs. time is shown in Figure 15-5 (p.280-281). Using these diagrams and Figure 1, produce a plausible explanation of the magmatic sources and components for the Columbia River Basalts, and describe how the amount each source contributed may have changed over time.
Not perfect correlation, but… most of the Columbia River basalts lie in between depleted mantle and enriched mantle components (I simplified the enriched mantle components by making them similar to bulk silicate earth). These are the earliest and most voluminous. In general, the first lavas were closest to depleted mantle (N-MORB), and as the eruptions progressed the isotopic signatures evolved towards having more of an enriched mantle component (lower mantle? Old underplated subducted oceanic crust?). The Saddle mountains represents the last little bit of magma, and these have a significant crustal component (old lower crust and shallower younger granites). Note the ambiguity: you don't need to invoke enriched mantle to explain these data- could just mix N-MORB with crustal stuff. Some people like to invoke enriched mantle because an argument can be made that these basalts are related to a "hot spot track" that leads to Yellowstone.

Figure 1.