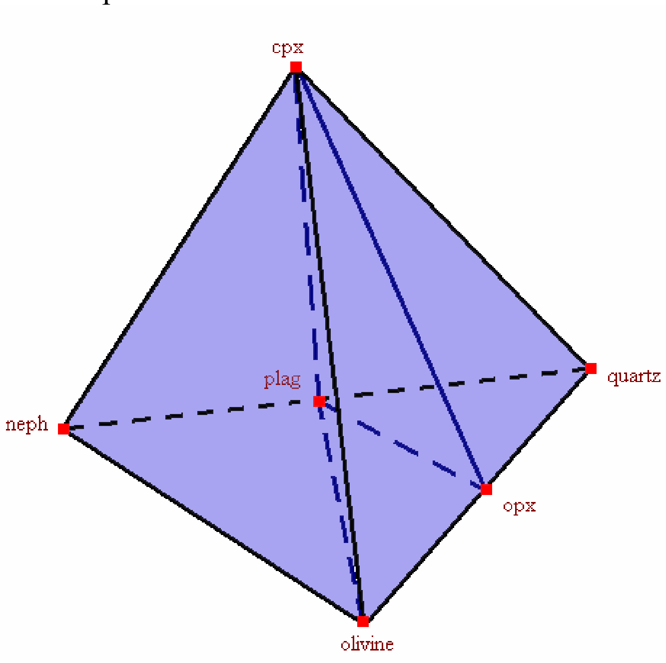
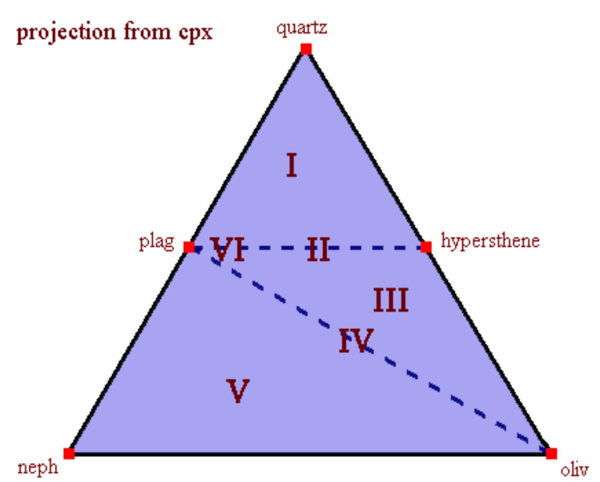
12.109 Petrology

<u>Basalts, basalt series, and basalt classification</u>

Basalt in the generic sense = plagioclase + clinopyroxene
+/- (olivine, nepheline, hypersthene, quartz, melilite, magnetite).

The basalt tetrahedron is a useful tool for classifying basalts. The tetrahedron is constructed using the normative components olivine, quartz, clinopyroxene, and nepheline.





There are six volumes in the tetrahedron that define the different groups:

	Name		Normative components
I	Quartz tholeiite	Oversaturated	Quartz and hypersthene
II	Tholeiite	Saturated	Hyp
III	Olivine tholeiite	Undersaturated	Olivine and hyp
IV	Transitional basalt or olivine basalt		No normative hyp, only oliv
V	Alkaline oliv basalt	Critically undersaturated	Oliv and nepheline
VI	High Al basalt	High Al from plag	Plagioclase

Note that there is a low pressure thermal divide (oliv-plag-cpx) that separates alkali olivine basalts from tholeiites.

Basalt series – We can think of three end member series, which represent the major types of basalt magmas and their fractionation products.

<u>Alkali olivine basalt series</u>

AOB > hawaiite > mugearite > trchyte > phonolite (pantellerite)

Rock series characteristic of oceanic islands and continental rift environments

Tholeiite basalt series

Tholeiite > andesite > dacite > rhyolite

Rock series characteristic of ocean floor and continental arc or island arc settings
Also, high alumina basalt can be the parent of this series

Are basalts produced by melting a single source? Or melting source regions of variable composition?

Melting experiments on simple systems and on natural basalts showed that the range of observed basalts could be derived by melting a single source region – IF melts were produced at different pressures
Alkali olivine basalts come from deep
Olivine tholeiites come from melting at shallower depths

Evidence – shrinking of olivine primary phase volume with increasing pressures. Melts at the olivine + high-Ca pyroxene (cpx) + low Ca pyroxene (opx) become more olivine rich as P increases

Multiple saturation hypothesis – where liquidus of a basalt is saturated with more than one mineral = multiple saturation point given T, P, and residue of melt generation

Older (1960s-1970s) model for basalt genesis involved melting in a single stage of mantle source of fixed composition. This model was generally successful but had several shortcomings:

I. Basalts in nature never saturated with all the phases that would be expected to be present in a mantle source. E.g. usually a basalt has olivine and hi-Ca pyroxene on its high pressure liquidus – it should also have low-Ca pyroxene (opx) as this is the second most abundant solid phase in a mantle peridotite source and an aluminous phase.
II. Basalt magmas rarely have MgO and FeO that are in equilibrium with Mg and Fe in mantle phases. The minerals in basalts are richer in FeO and poorer in MgO, indicating that melt has cooled, crystallized, and become modified during process of ascent and after melting from the original source. Modifying processes could include aggregation/mixing of multiple partial melts and differentiation.

MORB (Mid Ocean Ridge Basalt) genesis – two inseparable processes:
1. melt generation 2. melt modification

1. partial melting -
    - near fractional
    - occurs during adiabatic ascent
    - mantle cools, melts, and continually changes composition

2. fractional crystallization
    - deep and/or shallow?
    - melt compositional variation provides evidence
    - minerals in MORB provide evidence

melting by adiabatic ascent:

$$\left.\frac{dT}{dP}\right)_q = \frac{\alpha g T}{C_P} \sim 1^{\circ}\mathrm{C/kbar} \text{ or } 0.3^{\circ}\mathrm{/km}$$ (see Hess, p. 102)

Dynamics of melting: melt forms an interconnected network at low melt fractions, along grain boundaries

Global trends of Na-Fe @ 8.0% MgO show high Na % associated with low Fe % and vice versa
Na reflects % fractional melting because Na is an incompatible element.
Fe reflects depth of melting – high FeO → high olivine content
{Depth to spreading center, crustal thickness, MORB chemistry} all interrelated