Abstract
The Steens Basalt (~16.7 Ma) of SE Oregon is the oldest member of the Columbia River Flood Basalt (CRF) event. The Steens flows were fed by dikes near Steens Mountain, and originally covered ~50,000 km³. At Steens Mountain, 100-250 flows are stacked in over 900 m of near vertical exposure. Changes up section are analogous to the cryptic layering typical of layered mafic intrusions.

Geology of the Steens
The Steens Basalt is roughly coeval with the Imnaha flows of the Columbia River Basalt (Fig. 1). Steens lavas erupted within no more than 300,000 years of the 16.73 Ma Steens magnetic reversal (Mankinen et al., 1985; Jarboe et al., 2008; 2010; 2011; Fig. 1B).

Whole Rock Chemistry
Stratigraphic Variations
The Steens Basalt is divided into Upper and Lower sections based on chem stratigraphic distinctions: the flows transition from more mafic and tholeiitic (Lower Steens) to more silica rich and mildly alkalic (Upper Steens) with increasing stratigraphic height (Fig. 3). Changes up section are evident in other major and trace elements, as well as whole rock and mineral isotope compositions (Fig. 4).

Mineral Chemistry
Olivine microprobe analyses appear to record temporal variations in magmatic conditions. A stratigraphically low flow has homogeneous olivine (cores and rims Fo#75-78), suggesting a well-equilibrated magma reservoir. Above it, a flow with similar MgO content has diverse olivine signifying recharge, mixing and incomplete equilibration; cores are Fo#85-87, and rims are as low as Fo#63. Clinopyroxene Mg# and anorthite content are highest from this sample (Mg# 67-77, An# 60-65), but samples above and below this height exhibit excursions to lower ranges (Mg# 60-73, An# 66-88). The majority of olivine grains are as low as Fo#63. Clinopyroxene Mg# and anorthite content are highest from cores are Fo#85-87, suggesting a well-equilibrated magma reservoir. Olivine of (P#Fo83) is unlikely to be in equilibrium with mantle; thus the liquid from which these olivines fractionated was differentiated to some degree. Above it, a more magnesian flow has diverse olivine signaling recharge, mixing and incomplete equilibration; cores are Fo#75-78, and rims are as low as Fo#63. Clinopyroxene Mg# and anorthite contents are highest from this sample (Mg# 67-77, An# 60-65), but samples above and below this height exhibit excursions to lower ranges (Mg# 60-73, An# 66-88).

Petrography
Steens lava textures range from aphyric to extremely plagioclase phyric. Modal olivine ranges up to 15% in some flows; phenocrystic pyroxene is rare. Coarsely plagioclase phyric olivine basalts. Flows contain up to 40% plagioclase, and rims are as low as Fo#63. Clinopyroxene Mg# and anorthite content are highest from cores are Fo#85-87, suggesting a well-equilibrated magma reservoir. Olivine of (P#Fo83) is unlikely to be in equilibrium with mantle; thus the liquid from which these olivines fractionated was differentiated to some degree. Above it, a more magnesian flow has diverse olivine signaling recharge, mixing and incomplete equilibration; cores are Fo#75-78, and rims are as low as Fo#63. Clinopyroxene Mg# and anorthite contents are highest from this sample (Mg# 67-77, An# 60-65), but samples above and below this height exhibit excursions to lower ranges (Mg# 60-73, An# 66-88). The majority of olivine grains are as low as Fo#63. Clinopyroxene Mg# and anorthite content are highest from cores are Fo#85-87, suggesting a well-equilibrated magma reservoir. Olivine of (P#Fo83) is unlikely to be in equilibrium with mantle; thus the liquid from which these olivines fractionated was differentiated to some degree. Above it, a more magnesian flow has diverse olivine signaling recharge, mixing and incomplete equilibration; cores are Fo#75-78, and rims are as low as Fo#63. Clinopyroxene Mg# and anorthite contents are highest from this sample (Mg# 67-77, An# 60-65), but samples above and below this height exhibit excursions to lower ranges (Mg# 60-73, An# 66-88).

A Rich Record of Open System Processes
The Steens Basalt crops out in a spectacular, km-thick sequence of ~200 thin (generally ~10 m) compound and single lava flows that were fed by NNE-striking dikes (Fig. 1A and 2).

Magma Recharge and Equilibration
Some samples record homogeneity in all 3 mineral phases at various stratigraphic heights (98 & 274 m), whereas others record heterogeneity in all analyzed phases (58, 101 and 125 m). This supports the idea that homogeneous magma chambers were periodically recharged to produce mixed, non-equilibrated magma chambers.

Future Work
1. Additional petrography and mineral chemistry to fully characterize all textures and phases in samples from the entire Lower Steens section.
2. Whole rock and isotopic analyses on newly acquired samples.
3. Assessment of geochemical and mineralogical data in the context of how the Steens lavas differentiated as they traversed through the crust.
4. Modeling with widely used petrological models (DePaolo AFOC, MELTS, EC-RAFC, etc.) and the new Magma Chamber Simulator (MCS) to fully describe the pre-eruptive magma conditions, as well as the range and combination of processes that served to differentiate the flows (recharge, fractionation, assimilation, and combinations thereof).

References Cited