Oxygen isotope composition of plagioclase from the Steens Basalt, Columbia River Basalt Province, SE Oregon

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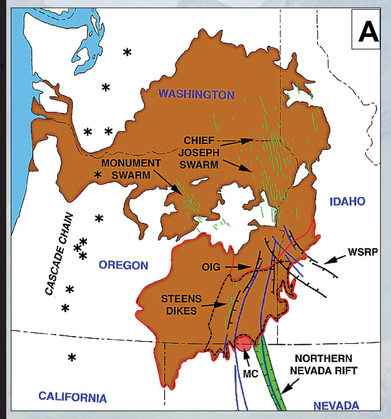
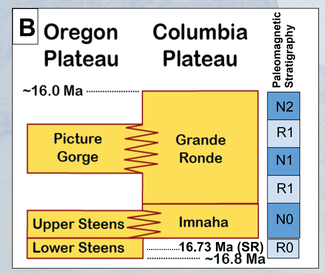
Introduction

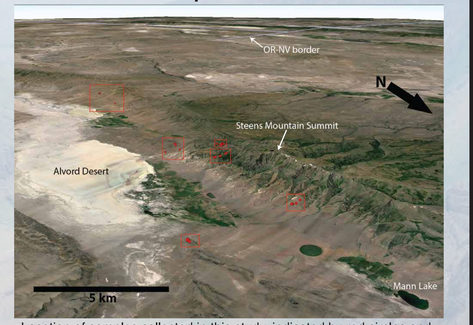
The Steens Basalt of SE Oregon is the oldest member and contains the most mafic compositions of the Columbia River Flood Basalt Group (CRBG). Steens lavas erupted within no more than 300,000 years of the 16.73 Ma Steens magnetic reversal.The lower Steens lavas are more mafic and incompatible element poor than upper Steens flows, which are less magnesian, mildly alkalic, and mainly basaltic andesites, much like the CRB proper.





(A) Regional map of the CRBG. Red line is approximate areal extent of lower Steens; dashed black line is upper Steens. MC, McDermitt caldera; OIG, OR-ID graben; WSRP, Western Snake River Plain. Modified from Camp & Ross (2004) and Camp & Hanan (2008).
(B) Schematic regional stratigraphy for the CRB. Paleomagnetic stratigraphy and Steens Reversal (SR) from Jarboe et al. (2008; 2010). Modified from Camp & Ross (2004), Camp & Hanan (2008) and Wolff & Ramos (2013).

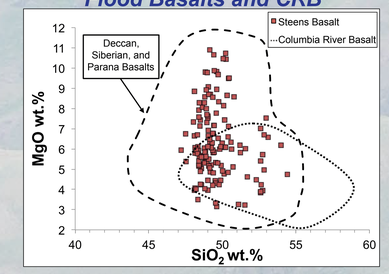
Overview Map of Steens Mountain



Location of samples collected in this study, indicated by red circles and outlined in red to highlight lateral sampling variability.

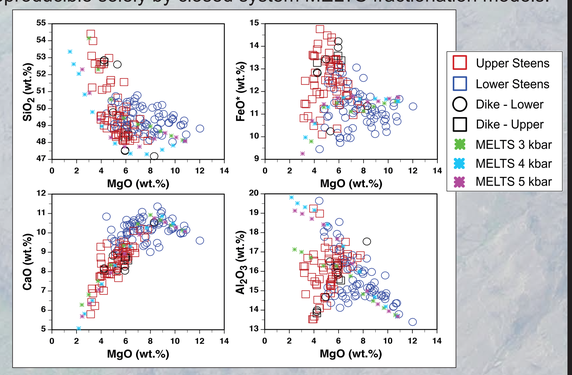
Whole Rock and Mineral Chemistry

Steens: A Bridge Between Global Continental Flood Basalts and CRB

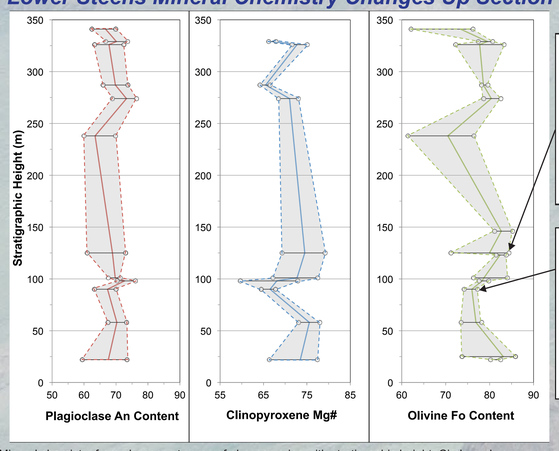


-Steens Basalts are the most mafic of all CRB; the bulk of CRB are basaltic andesites.
-Steens lie in a region of MgO v. SiO_2 space with the bulk of continental flood basalts.
-This character makes Steens lavas optimal to decipher the mantle history of the CRB.

Two two trends in the lower Steens (extended by upper Steens):
1.Increasing Al_2O_3/decreasing MgO at low FeO.
2.Increasing Al_2O_3/decreasing MgO until ~8 wt.%, then both decrease.
**Not reproducible solely by closed system MELTS fractionation models.

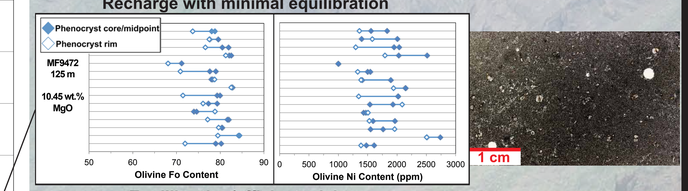


Lower Steens Mineral Chemistry Changes Up Section

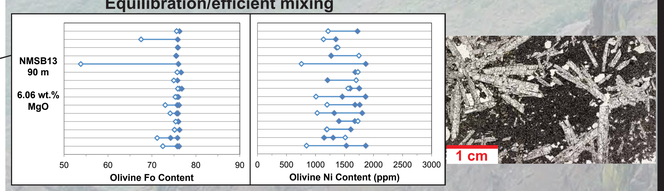


Mineral chemistry from phenocryst cores of phases varies with stratigraphic height. Circle end caps represent max and min values from each sample. Solid colored line intersects at average value of core compositions.

Recharge with minimal equilibration

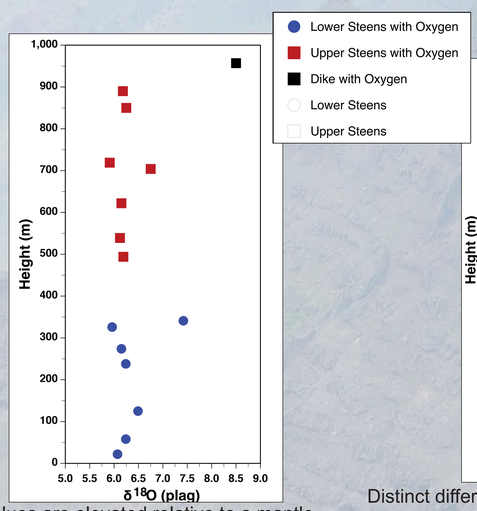


Equilibration/efficient mixing



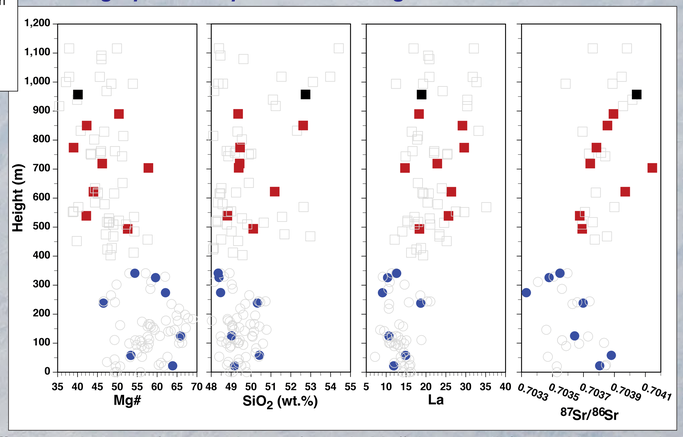
Take away points this section:
-Steens lavas are most mafic of all CRB, more like other CFB.
-Lower Steens dominated by fractionation and recharge with periods of equilibration.

Oxygen Isotopes



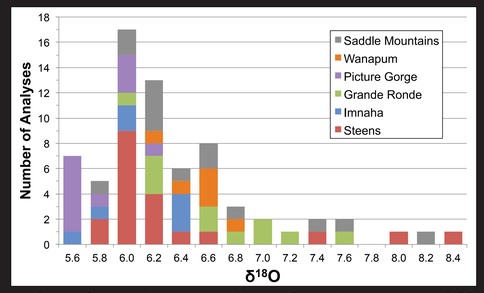
Values are elevated relative to a mantle source which is likely due to assimilation of crustal material with a higher $\delta^{18}O$.

Stratigraphic Compositional Changes in the Steens Basalt



Distinct differences between lower and upper lavas in Mg#, incompatibles and isotopes, but $\delta^{18}O$ values for upper Steens are barely higher on average (mode = 6.2) relative to lower Steens (mode = 6.1).

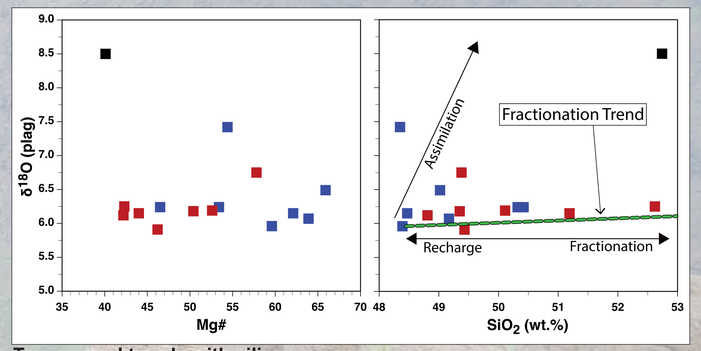
Comparison of Oxygen Isotopes with other CRB



Most mafic are Steens, Imnaha and Picture Gorge (lowest overall $\delta^{18}O$).
Even most primitive compositions are somwhat differentiated, for Steens:
1. Mode ~6.0‰ is ~0.5‰ lower than expected mantle.
2. Fo content of olivine in Steens lavas are ≤86.
3. Mg# of more primitive lower Steens is ≤66.

Most of the CRB have elevated $\delta^{18}O$, consistent with crustal contamination.

*Steens data from plagioclase, this study. Other CRB data from whole rock, as compiled by Brandon et al. 1993.



Two general trends with silica:
1. Slightly increasing $\delta^{18}O$ (5.9 to 6.3‰) over 48-53 wt.% SiO_2 (with decreasing Mg# from 65 to 40).
2. Markedly increasing $\delta^{18}O$ (5.9 to 8.5‰) over the same SiO_2 range.

Take away points from this section:
-Fractionation and/or recharge dominates oxygen isotope signature.
-Some crustal assimilation likely in Steens and most of the CRB.

Conclusions

1. The first trend in $\delta^{18}O$ versus silica, defined by most of the data, is likely caused by crystal fractionation outcompeting recharge as the magma system evolves.
2. The trend with excursions to high $\delta^{18}O$ suggests some crustal assimilation did occur.
3. Crustal assimilation apprears to be a minor part of the O mass balance, particularly:
   a. compared to crystal fractionation (expected to elevate $\delta^{18}O$ by a scant permil over this compositional range).
   b. compared to recharge (hypothesized to buffer $\delta^{18}O$ to a parental composition at ~6‰).

References Cited
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