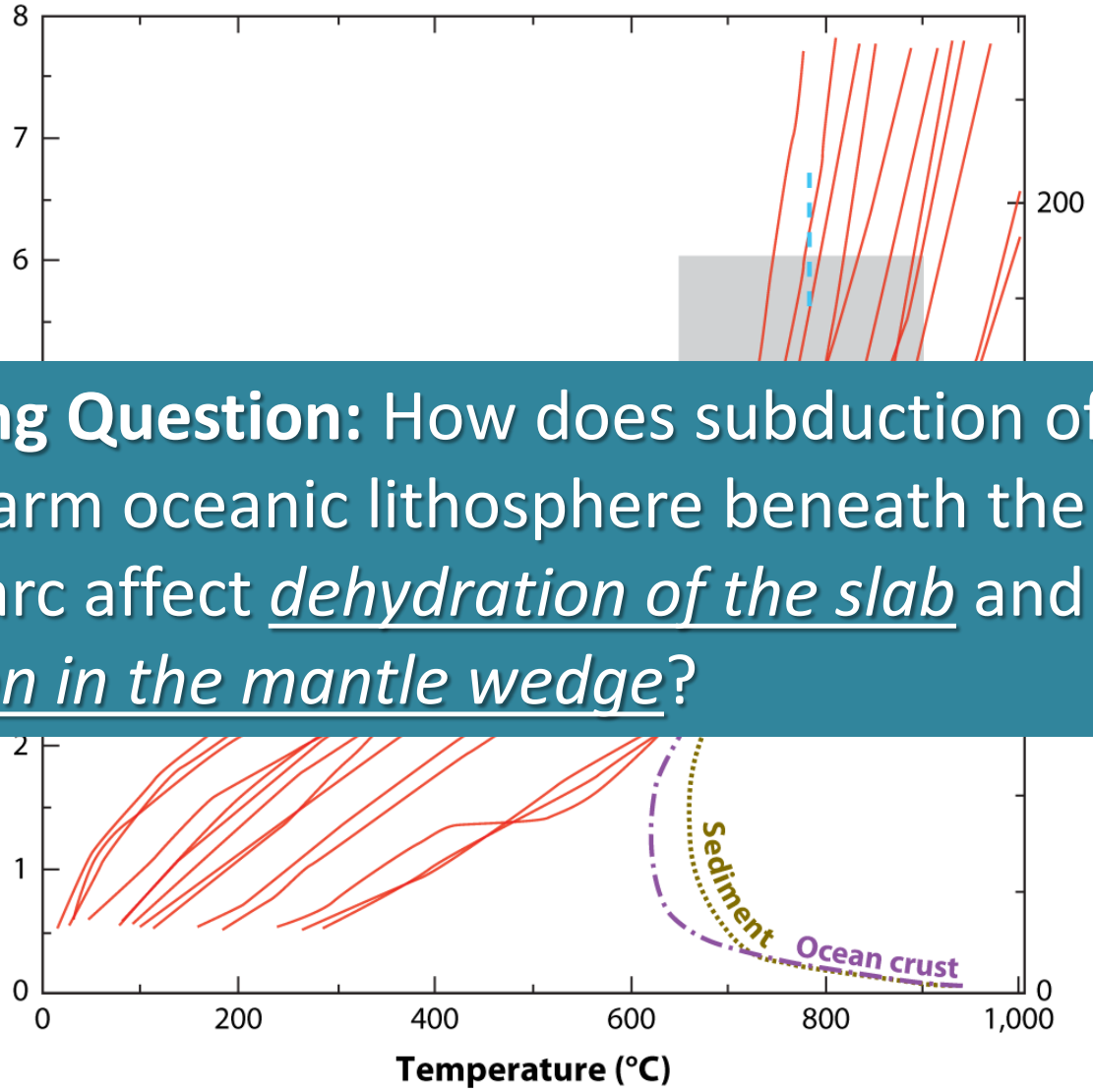
Slab melting beneath the southern Cascade Arc driven by dehydration of altered oceanic peridotite

Kristina Walowski,[1,2]
Paul Wallace [1], Michael Clynne [3], Ikuko Wada [4], Erik Hauri [5]
Dan Rasmussen [6], Dominique Weis [7]
[1]University of Oregon, [2]University of Edinburgh, [3]US Geological Survey
[4]University of Minnesota, [5]DTM, Carnegie Institution of Washington,
[6]Lamont Doherty Earth Observatory, [7]University of British Columbia

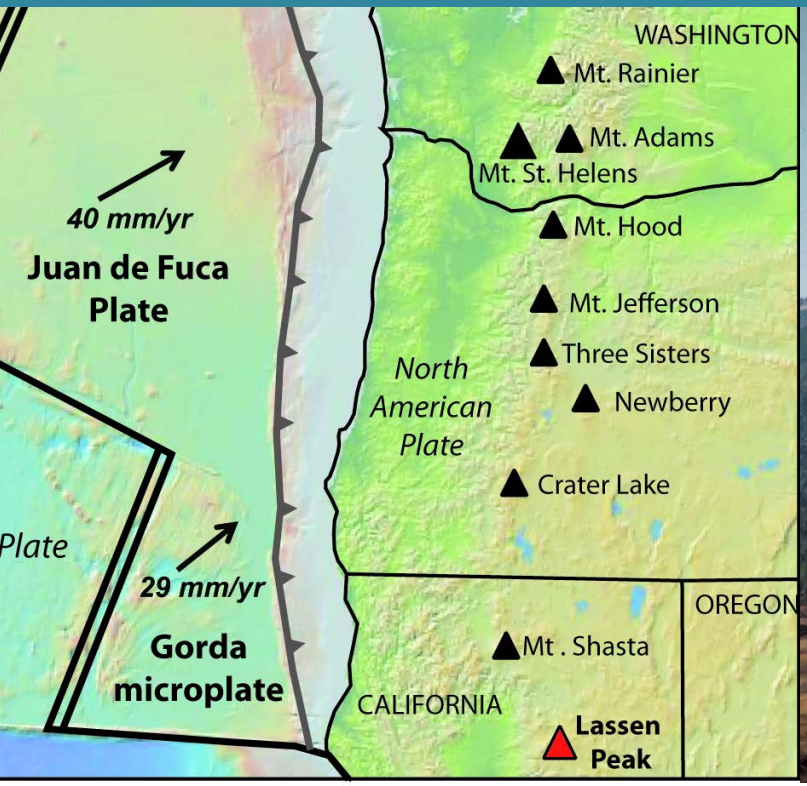
Modeled Slab Top P-T Paths



Motivating Question: How does subduction of young, warm oceanic lithosphere beneath the Cascade arc affect *dehydration of the slab* and *melt production in the mantle wedge*?

Grove et al. (2012)

The Lassen Region

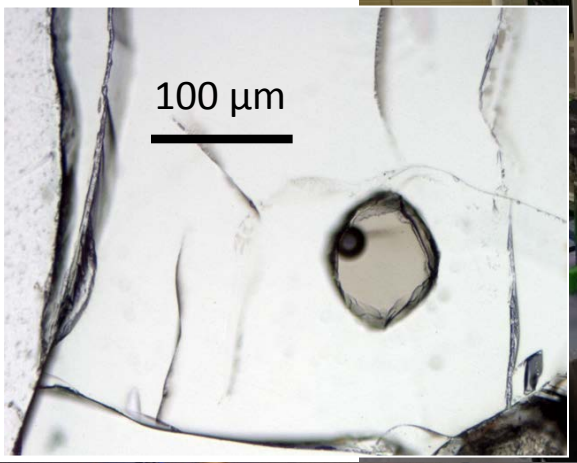


- **Magmatism is related to oblique subduction of the Gorda microplate**

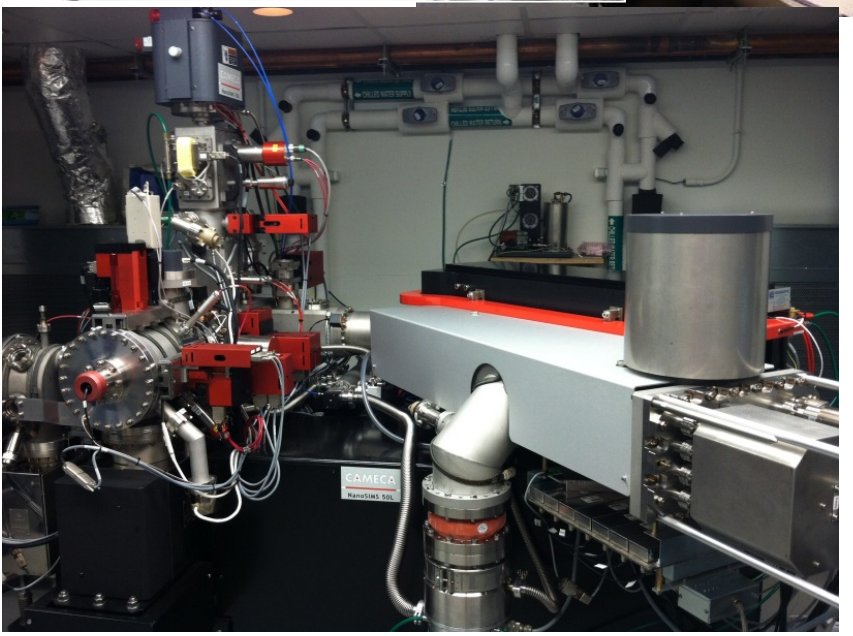
- **Lassen Region has an extensive cinder cone field, with across-arc geochemical variations related to subduction enrichment**

Samples:

- **Primitive (MgO > 7wt%) basaltic tephra from 7 cinder cones**



Above: SIMS 1280 at WHOI



Upper left: photo micrograph of a melt inclusion
Above: NanoSIMS 50L, Carnegie Inst. of Washington

Methods

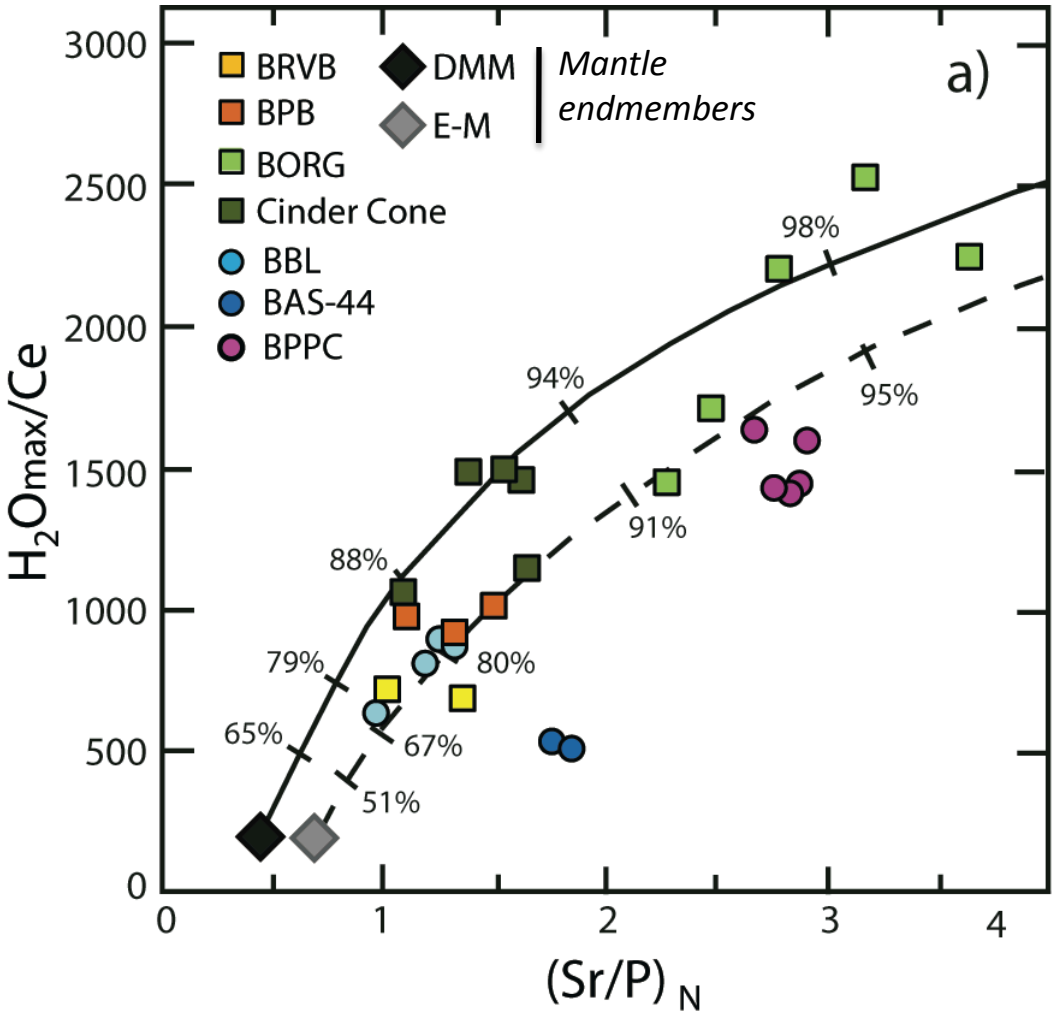
Olivine-hosted melt inclusions:

δD and H_2O: NanoSIMS at the Carnegie Institute of Washington
B Isotopes: SIMS 1280 at Woods Hole Oceanographic Institution
H_2O and CO_2: FTIR at University of Oregon
Major Elements: EPMA, University of Oregon
Trace elements: LA-ICP-MS at Oregon State University

Bulk Tephra:

Radiogenic Isotopes – University of British Columbia

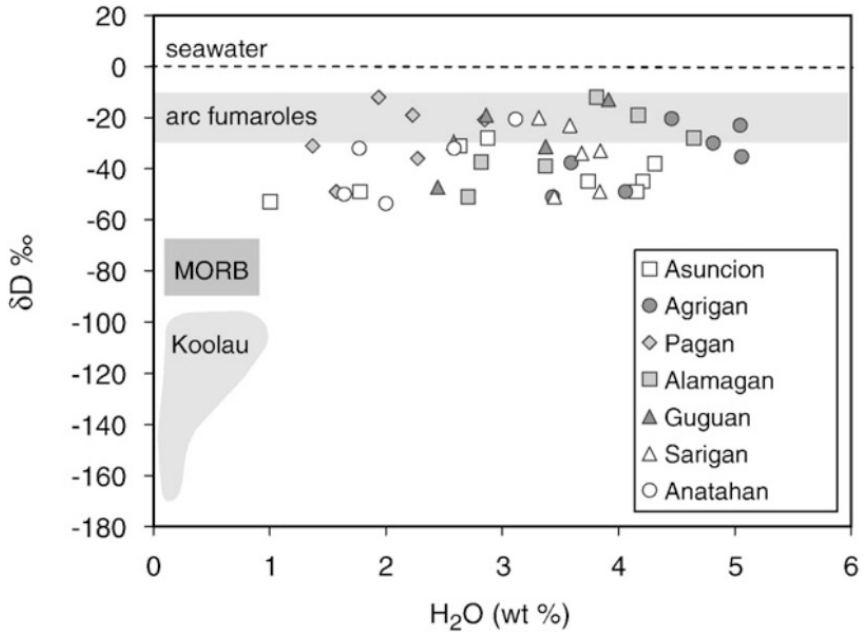
H_2O and Trace Elements in Lassen Region Magmas

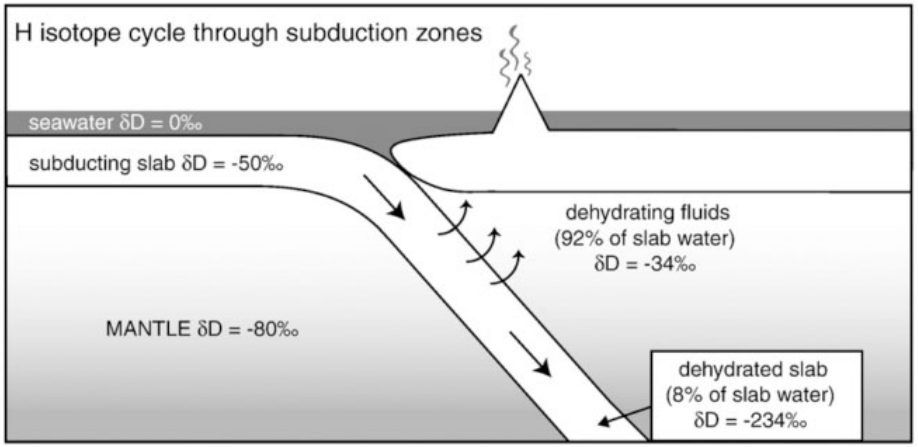


- Correlation of volatiles and LILEs indicates variable addition of a hydrous subduction component.
- Mixing calculations show that the subduction component accounts for 70-98% of the H_2O dissolved in Lassen region mafic magmas.

Walowski et al., (2015)

Hydrogen Isotopes

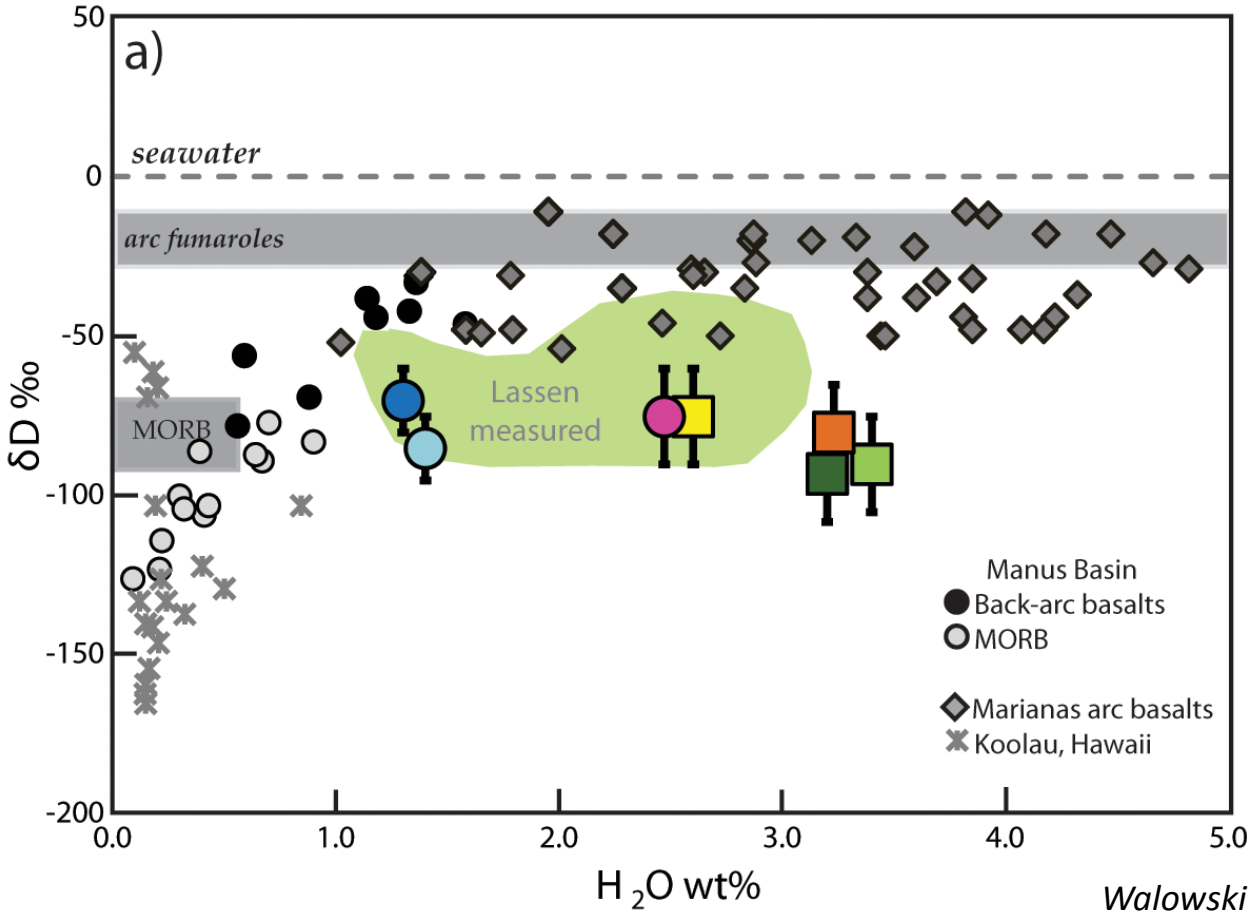




Both figures from Shaw et al., (2008)

- **Shaw et al., (2008)** show Mariana arc melt inclusions have δD values elevated with respect to MORB.
- Strong fractionation of D/H during slab dehydration forms a D-enriched hydrous slab component and a complimentary D-depleted residual slab.

Hydrogen Isotopes

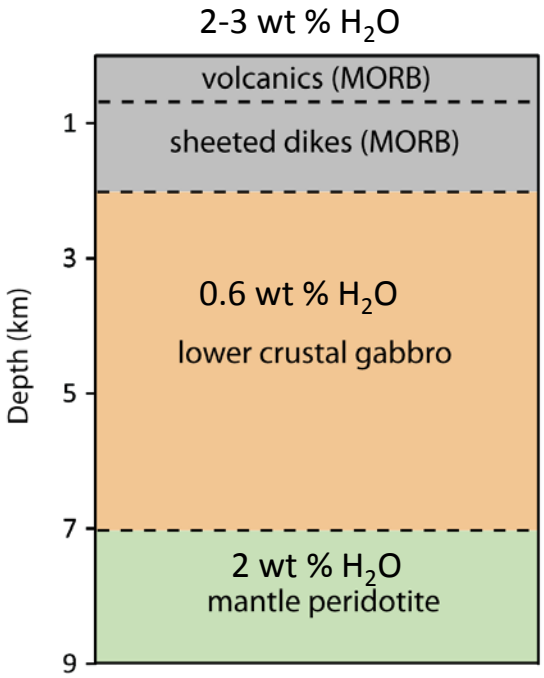


Walowski et al., (2015)

- **Lassen melt inclusions are corrected for diffusive loss of hydrogen by methods of Bucholz et al., (2013).**
- **Measured and corrected δD values are isotopically lighter than those previously measured in the Marianas**

Modeling H_2O release from the slab

The Model: Wada et al. (2012)
Couple 2-D thermal models (Wada and Wang, 2009) with metamorphic phase equilibria using Perple_X (Connolly, 2009) to calculate H_2O flux from the slab.



Assumptions:
- 2 km of mantle hydration
- vertical fluid migration
- Excludes sediment package

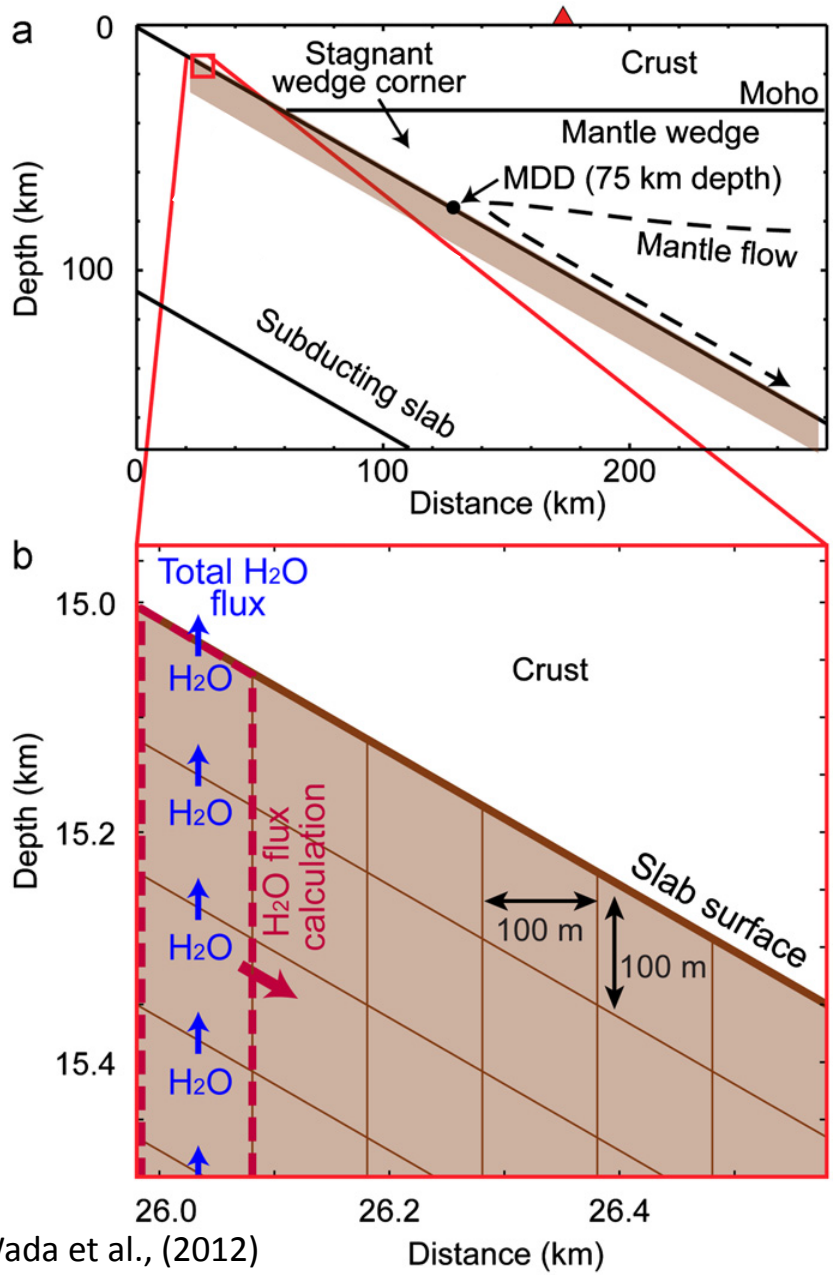
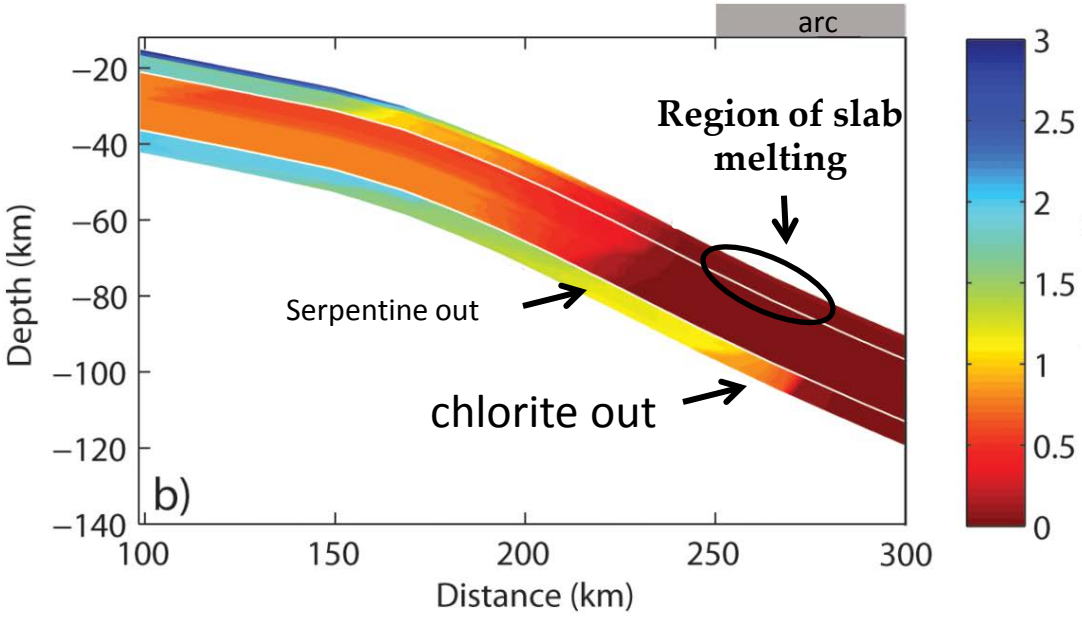
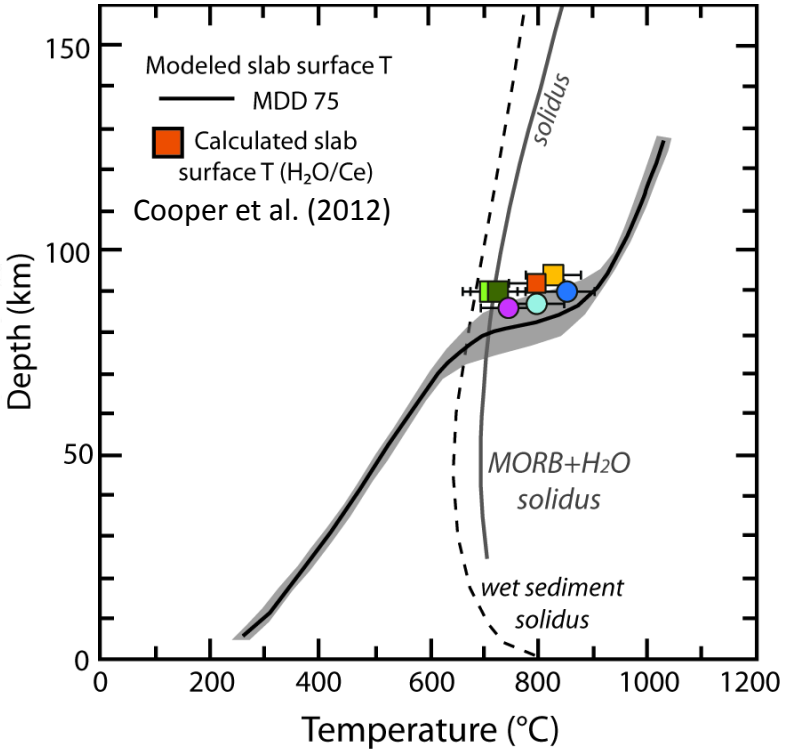


Figure from Wada et al., (2012)

H_2O Release and Slab Surface T



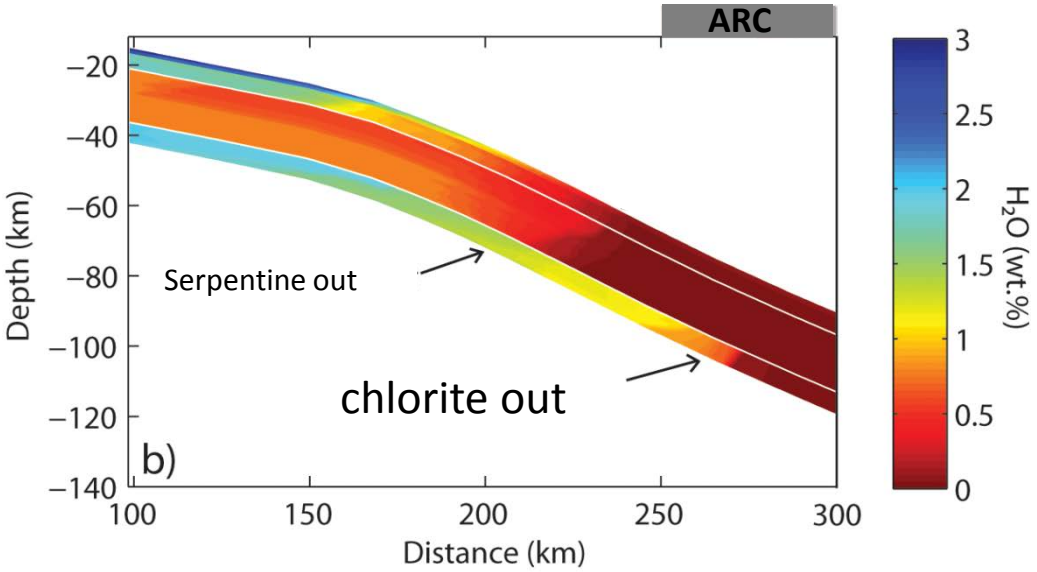


Walowski et al., (2015)

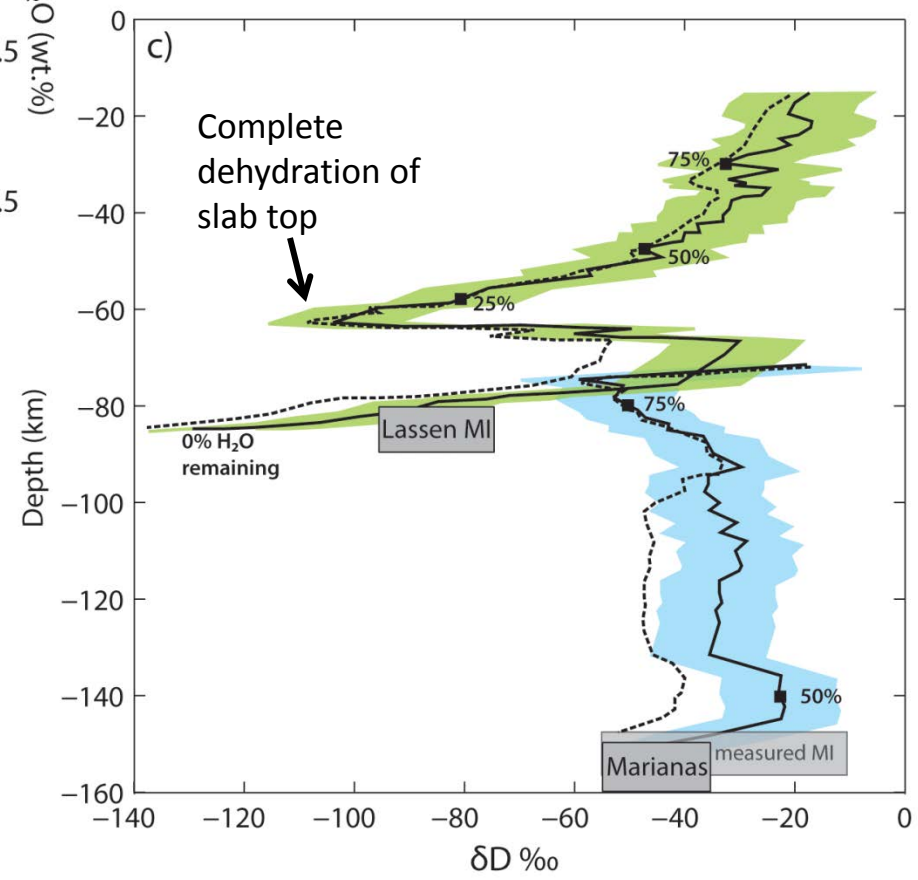
- **Thermo-mechanical model results for slab dehydration shows two fluid pulses**

- **Because slab surface temperatures are at or above the MORB + H_2O solidus, the upper oceanic crust is likely flux-melted by fluids rising from the slab interior.**

D/H Fractionation Model Results

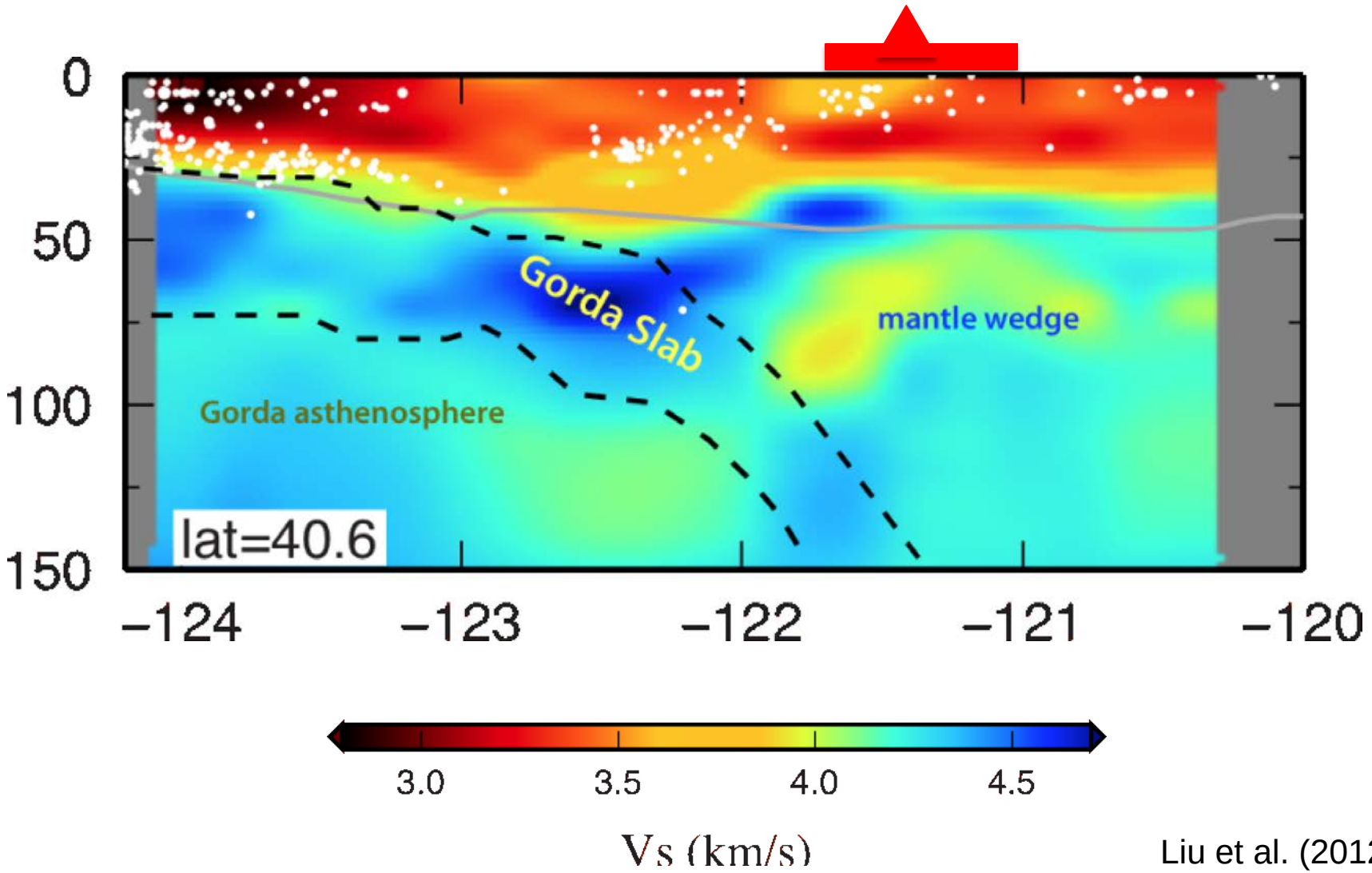


Walowski et al., (2015)



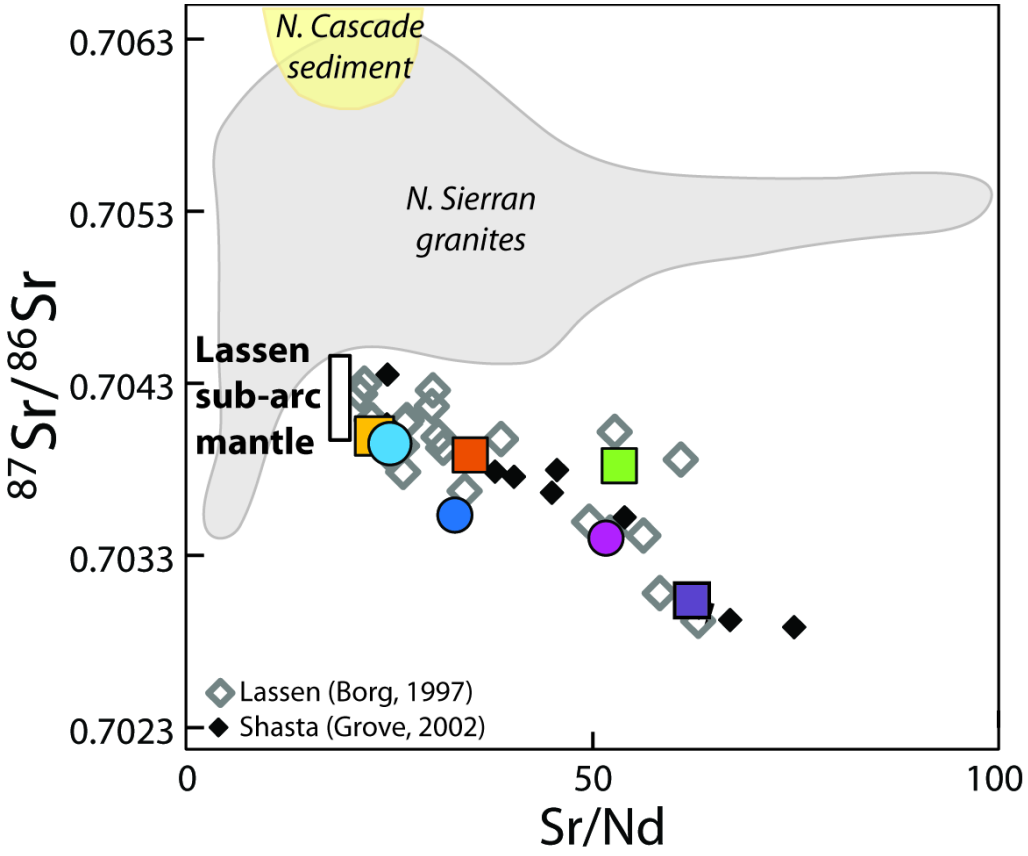
- **Dehydration models suggest that initial δD values of the melts reflects the waning dehydration of the slab interior (final chlorite breakdown in the hydrated upper mantle portion of the slab).**

Shear Velocity Model for the Lassen Region



Liu et al. (2012)

Sr Isotopes in Southern Cascade Magmas



Walowski et al., in review

- The subduction component beneath the southern Cascades is less radiogenic than the sub-arc mantle wedge
- Inconsistent with addition of seawater-derived Sr from altered oceanic crust

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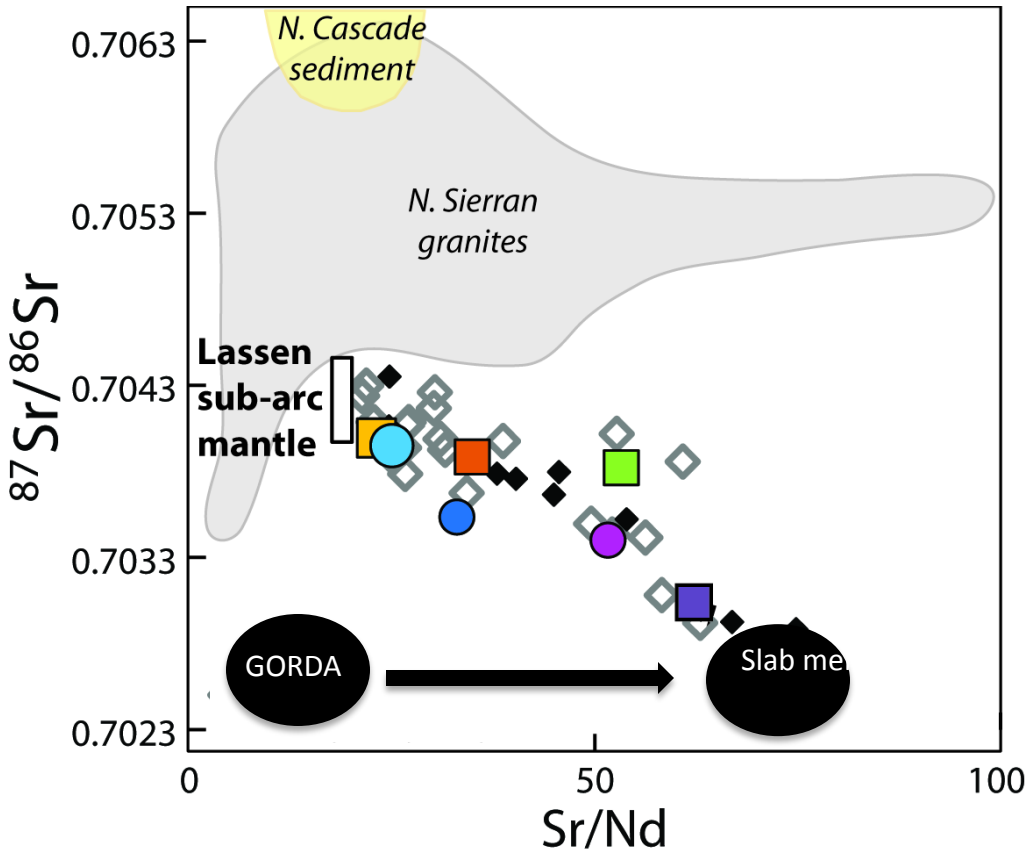

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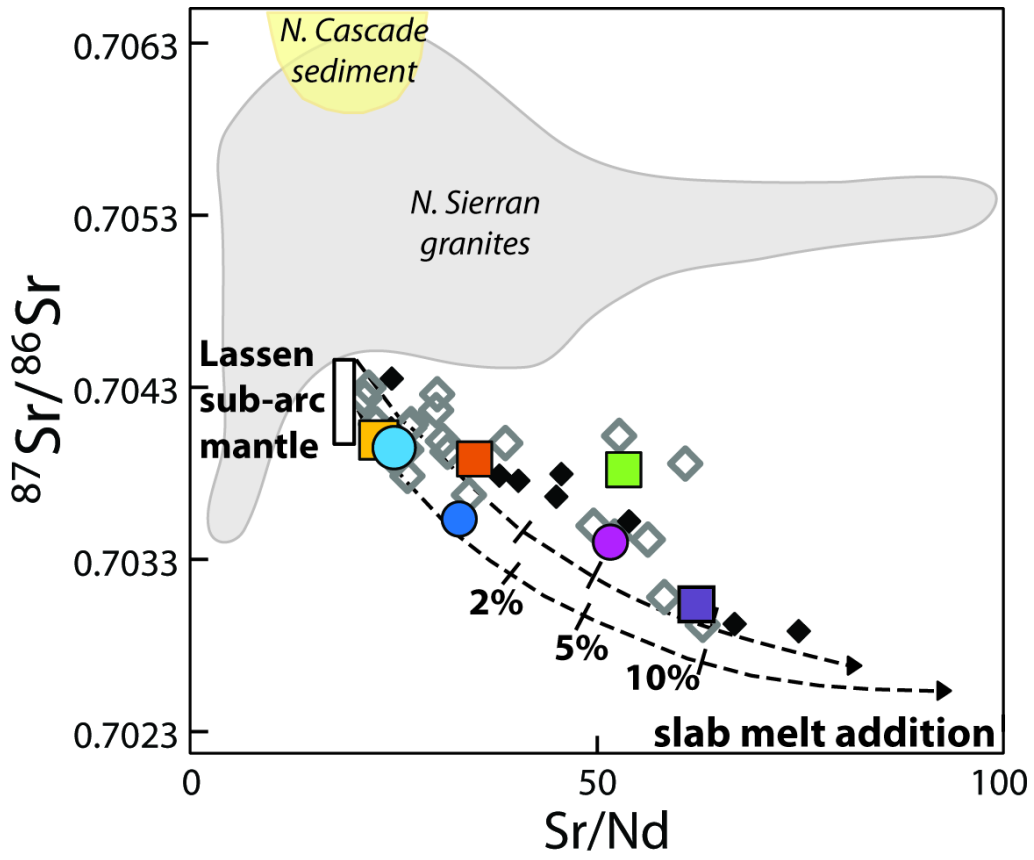


Walowski et al., in review

- The radiogenic isotope composition of the Lassen region primitive magmas can be explained by 1-10% slab melt addition to the mantle wedge
- some variation might be related to a sediment melt component

How do slab melts affect wedge peridotite melting?

Model Assumptions

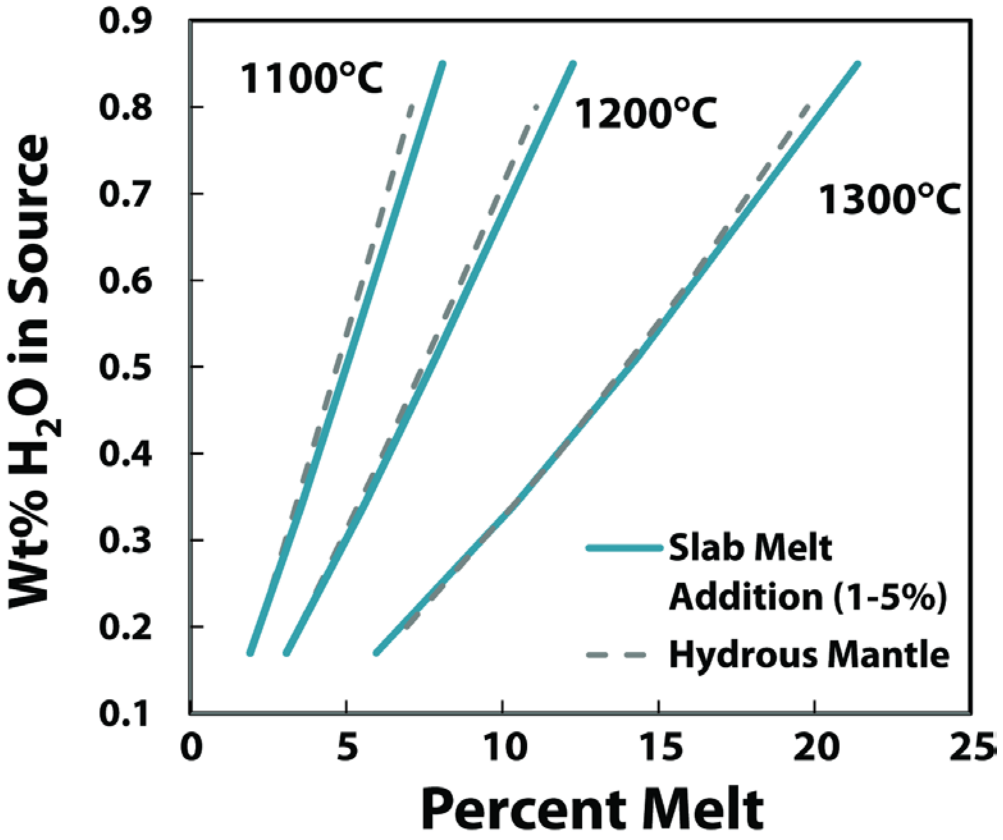
- pMELTS (Ghiorso et al., 2002)

- bulk equilibrium melting of mantle peridotite with variable addition of hydrous slab melt

- variable T (900-1400 °C), constant P (1.5 GPa)

Compositions:
- MM3 peridotite composition (Baker and Stolper, 1994), which closely approximates various estimates of primitive upper mantle
- Dacitic melt with 8 wt% H_2O from basalt melting experiments of Klimm et al. (2008)

pMELTS Model Results



Walowski et al., in review

- Mantle melt fraction is dominantly controlled by H_2O concentrations
- Alkalis also have a small fluxing effect on peridotite melting

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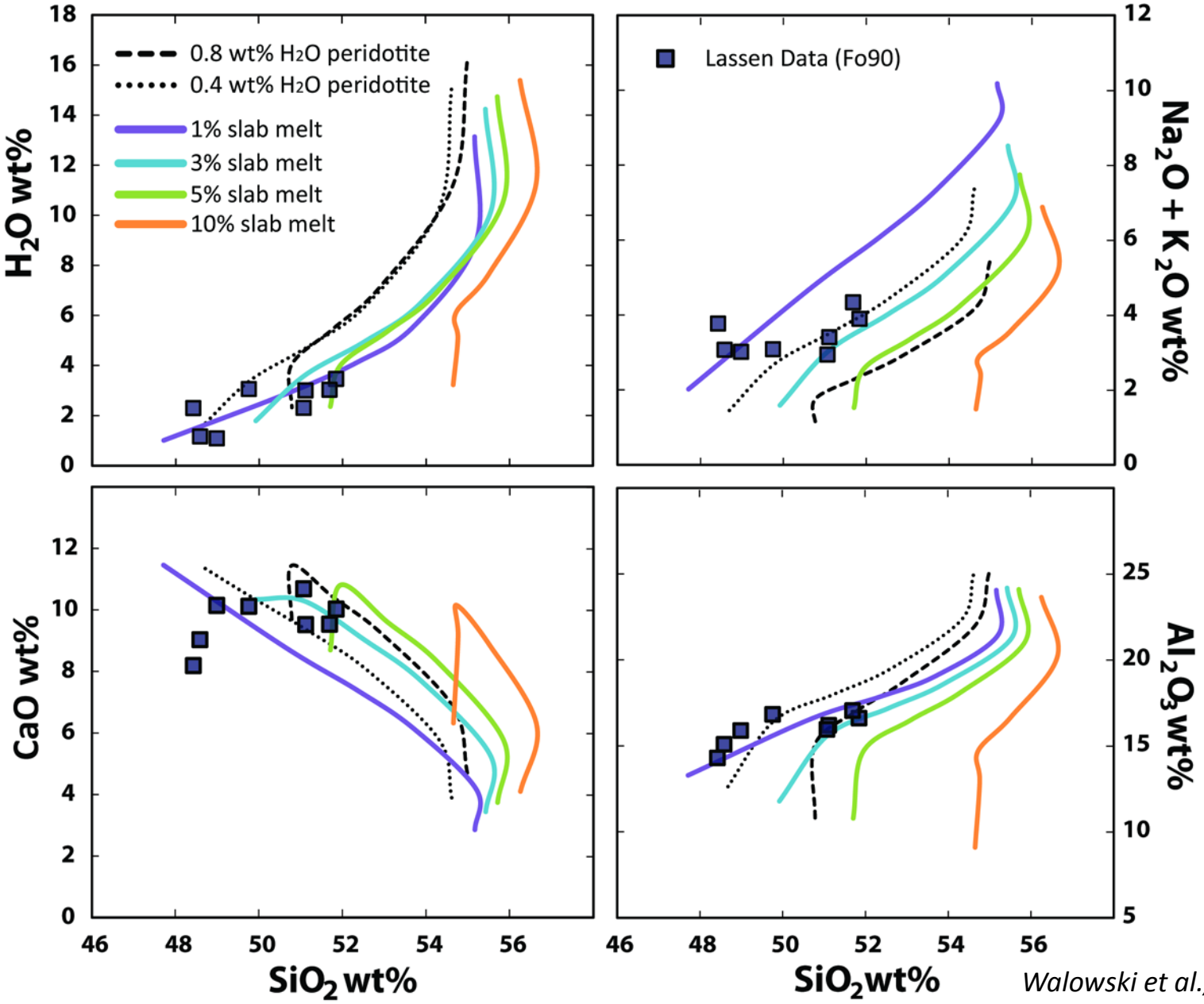

Walowski et al., in review

Conclusions

Evidence for slab melting:

- Low δD values in southern Cascades reflect the waning dehydration of the slab interior (chlorite breakdown in subducted oceanic mantle).
- Because slab surface temperatures are at or above the MORB + H_2O solidus, the upper oceanic crust is likely flux-melted by fluids rising from the slab interior
- MORB-like Sr isotope compositions are consistent with a partial slab melt component in the most enriched magmas

pMELTS model results:

- H_2O controls mantle wedge melting regardless of whether it is introduced as a melt or aqueous fluid
- Major element compositions of S. Cascade magmas can be explained by small amounts of slab melt addition