POLYGENETIC POST-LARAMIDE MANTLE LITHOSPHERE BENEATH THE MOJAVE DESERT: THE XENOLITH RECORD

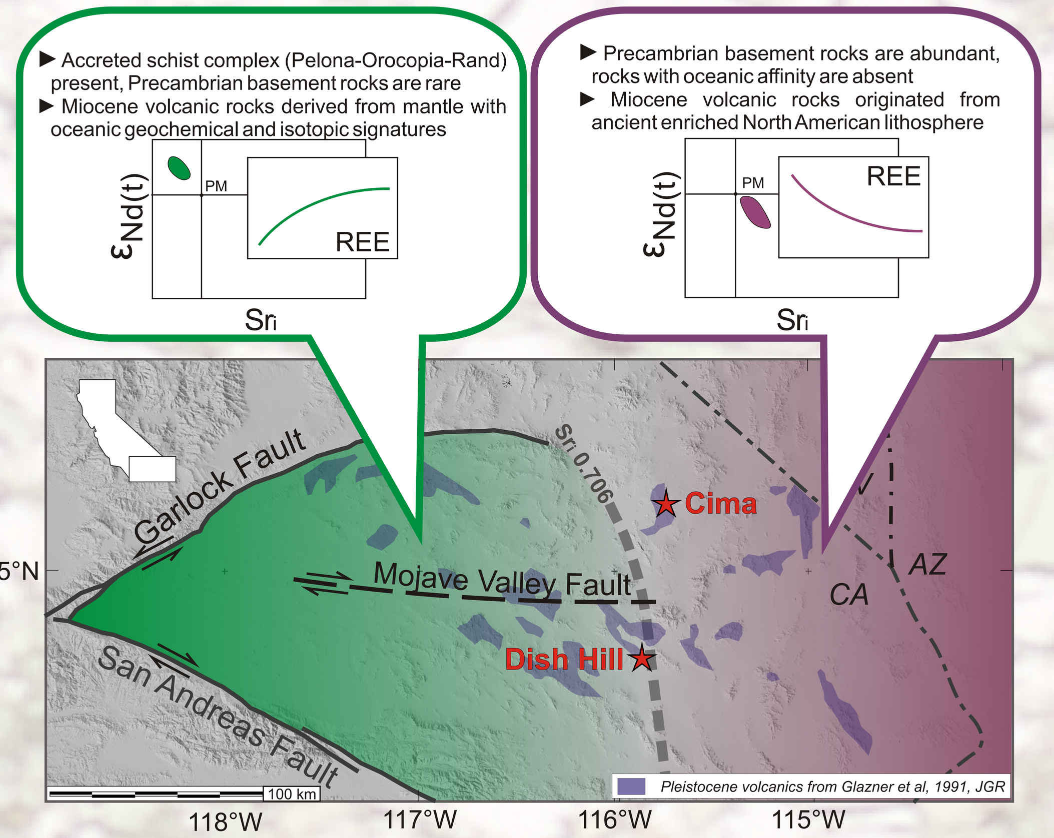
Peter I. LUFFI[1]*, Jason B. SALEEBY[1], Mihai N. DUCEA[2]

[1] Division of Geological & Planetary Sciences, California Institute of Technology, [2] Department of Geosciences, University of Arizona

*e-mail: pluffi@gps.caltech.edu

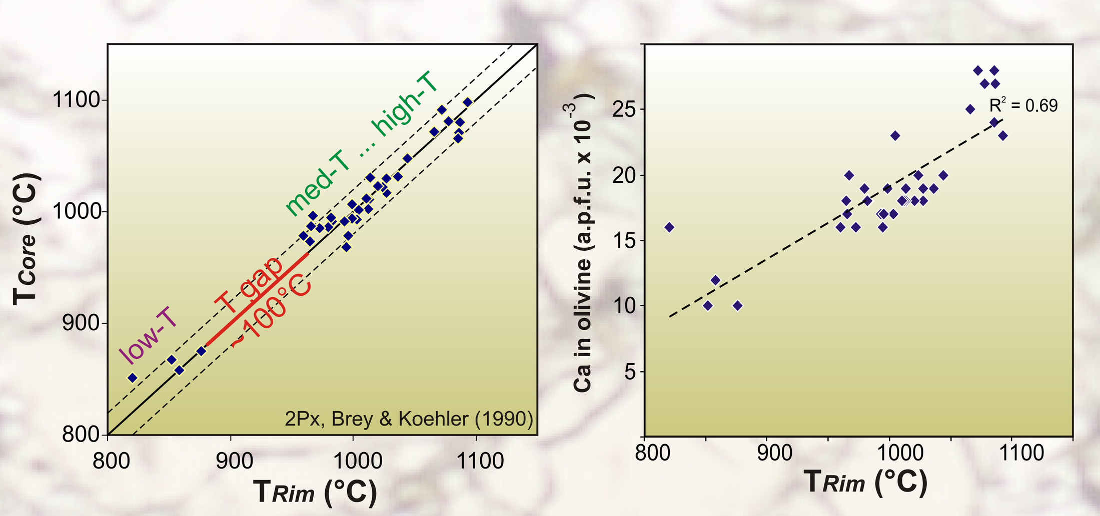
1. Introduction

Sr, Nd and Pb isotope composition of mantle-derived lavas from the Mojave Desert reveal regional scale heterogeneities of the deep lithosphere in the Miocene [Miller et al., 2000, GSA Bull]: enriched Precambrian sub-continental lithospheric mantle (SCLM) of North America has underlain the eastern part of the Desert, whereas depleted, young Farallon oceanic mantle has dominated its western part. The boundary between these domains coincides with the Sr_i = 0.706 line of Kistler and Peterman [1973, GSA Bull]. In the eastern part of the Mojave Desert this model is sustained by trace element and radiogenic isotope enriched peridotite xenoliths erupted in the Cima volcanic field in Plio-Pleistocene times [Mukasa & Wilshire, 1997, JGR]. Late Pleistocene-Holocene basanites from Dish Hill, Central Mojave Desert, erupted close to the hypothesized boundary between these mantle domains, and contain xenoliths which can help 1) refine the boundary conditions between the inferred mantle domains, and 2) evaluate whether the lithospheric mantle structure of the Mojave Desert has changed significantly after Miocene.



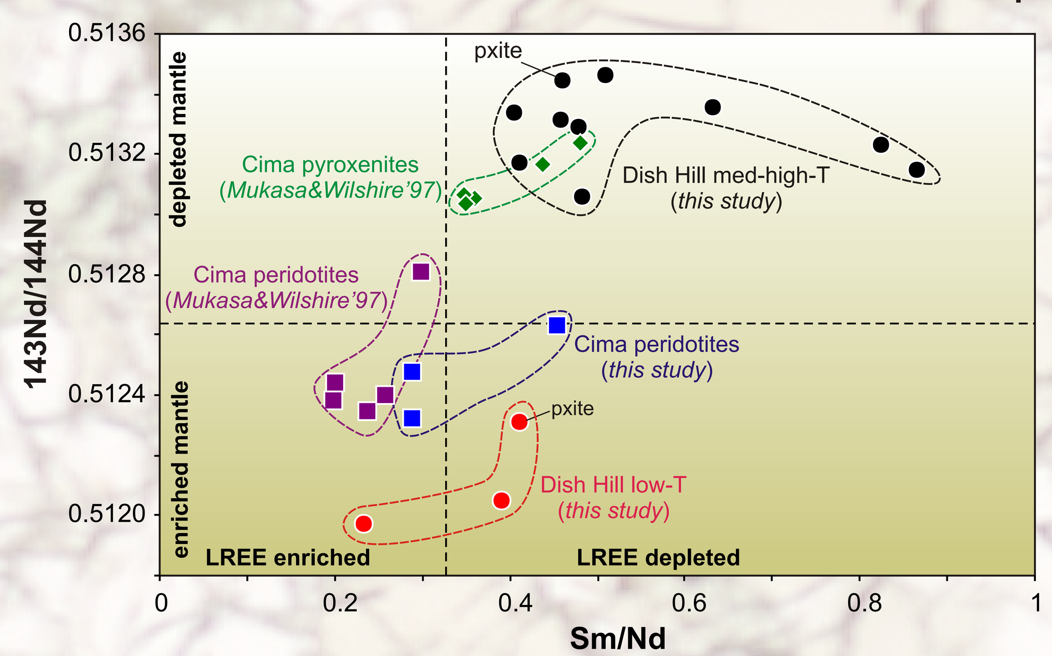
2. Dish Hill xenoliths

Geothermometry



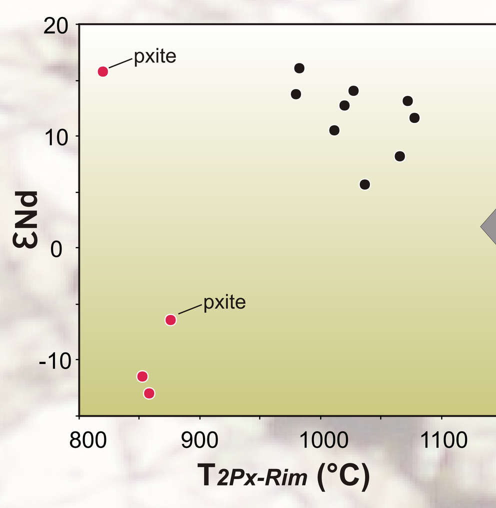
Two-pyroxene geothermometry [Brey & Koehler, 1990, JP] based on core-core and rim-rim composition pairs suggest that neither systematic cooling nor heating events are recorded by the Dish Hill xenolith suite (dashed lines correspond to the thermometer's ±20ºC uncertainty). Ca contents in olivine loosely correlate with two-pyroxene temperatures, but derivation of a meaningful geotherm is impossible due to the large uncertainties associated to the Ca-in-olivine geobarometer [±4 Kbar, Koehler & Brey, 1990, GCA, Brey & Koehler, 1990, JP]. This correlation nevertheless suggests that if a qualitative pressure correction to the 15 kbar reference pressure used for geothermometry would be applied, the temperature range covered by these xenoliths would increase with 20-30ºC. Assuming a local geotherm in the 16-25 °C/km range, the xenoliths are representative for a 10-15 km mantle column located somewhere in the 33-68 km depth range.

Compositions



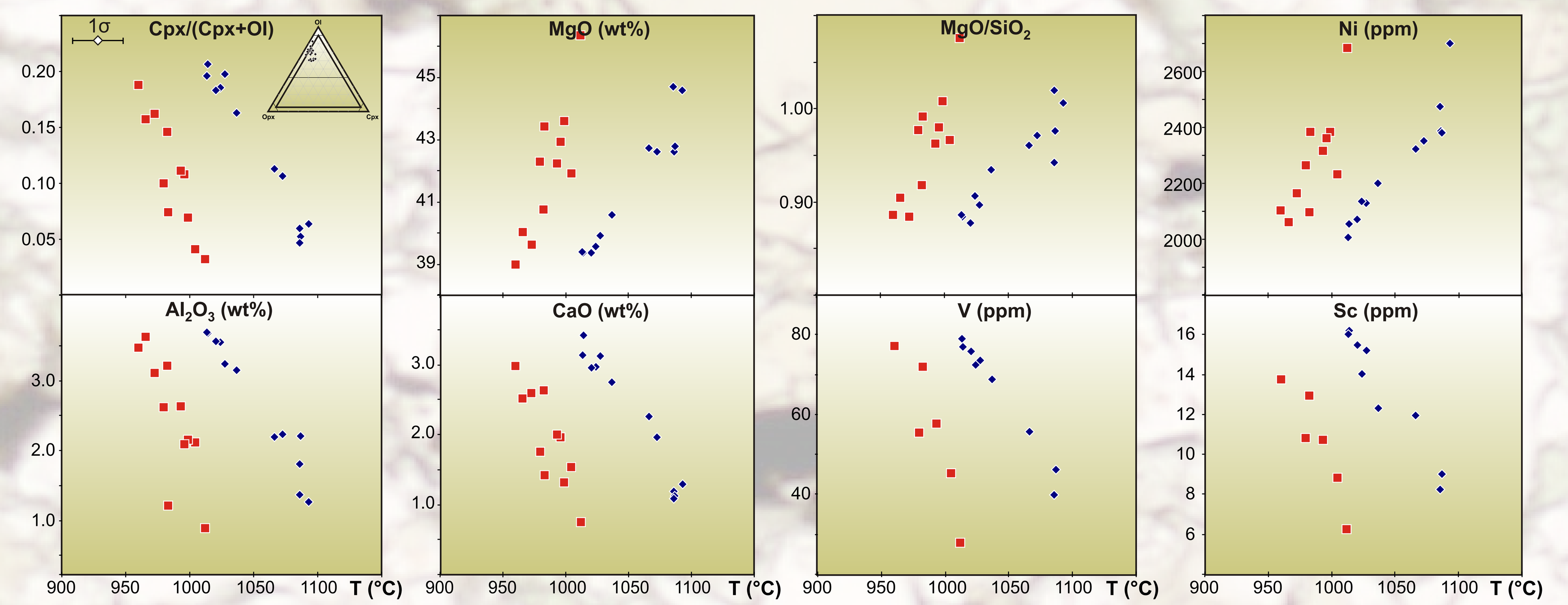
Sm/Nd vs. $^{143}Nd/^{144}Nd$ in clinopyroxenes from Dish Hill and Cima xenoliths. The four quadrants of the diagram distinguish coupled Sm/Nd ratios and Nd isotopic compositions (lower left and upper right fields) from decoupled ones (upper left and lower right fields). Xenoliths with $^{143}Nd/^{144}Nd$ plotted in the upper right quadrant are derived from a mantle source depleted in LREE, those with $^{143}Nd/^{144}Nd$ plotted in the lower left quadrant have they source in a mantle enriched in LREE for a considerable period of time. Xenoliths plotted in the other two quadrants likely have been disturbed by relatively recent metasomatic processes. Low-T xenoliths from Dish Hill and Cima Cr-diopside peridotites appear to derive from the same enriched continental mantle, whereas medium- and high-T xenoliths from Dish Hill are similar to the mantle source of Cima pyroxenites, and may be of Farallon origin.

Temperature - composition relationships

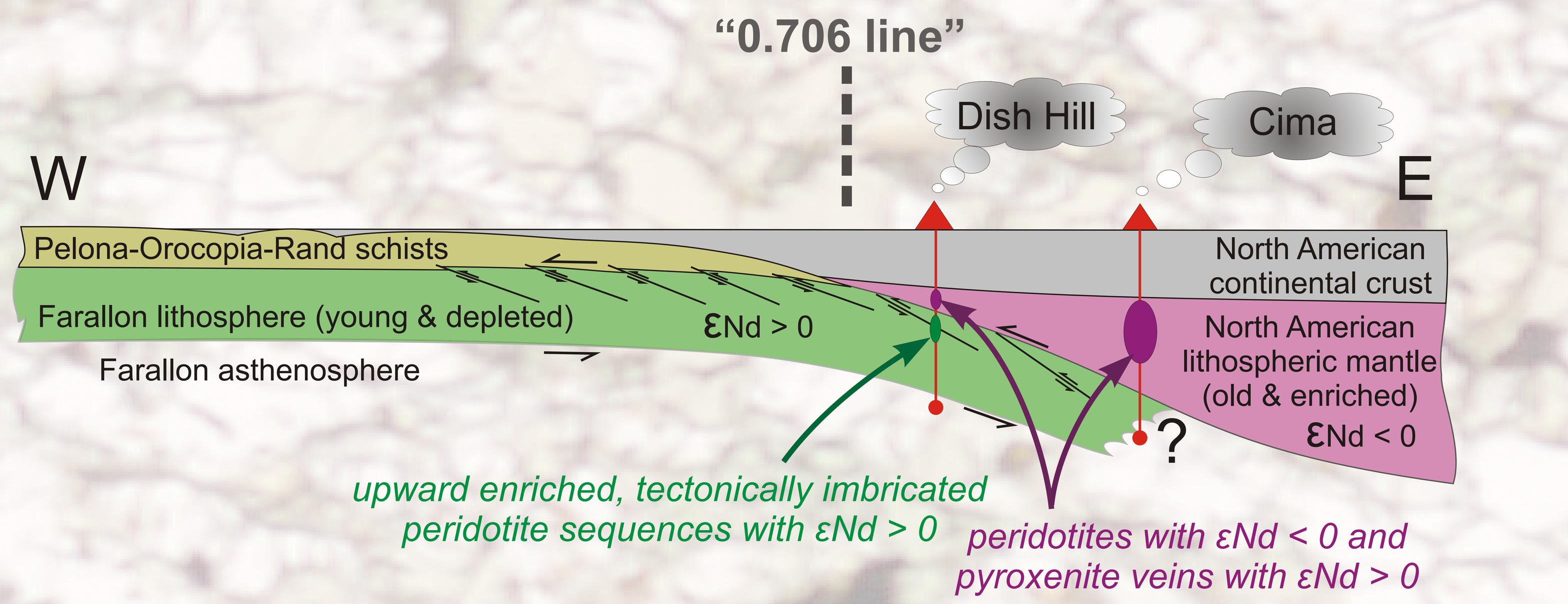


T_{2Px} vs. εNd for Dish Hill xenoliths. Medium- and high-T samples display a loose negative correlation between T_{2Px} and εNd, suggesting poor correlation between depth and depletion. Low-T xenoliths do not share this trend; therefore the gap in the lithospheric mantle beneath Dish Hill is likely both thermal and isotopic.

T_{2px} vs. bulk rock major and trace elements in medium- and high-T xenoliths from Dish Hill. Remarkably, medium- and high-T samples share the same, but thermally divided trends. This suggests that the deeper, high-εNd mantle section beneath Dish Hill is characterized by a double layered architecture, in which each layer display a top-to-bottom depletion zoning.



3. Inferred mantle structure beneath the Mojave Desert



Nd isotope data combined with geothermometry results indicate that the E-W horizontal heterogeneity of the Mojave mantle inferred from lava geochemistry may be identified as vertical heterogeneity beneath Dish Hill.

Here, the uppermost mantle is relatively cold, enriched and old (T= 850-900°C, εNd = 6.4 to 13, T_{DM} > 2Ga), and corresponds to the ancient SCLM represented by xenoliths from the Plio-Pleistocene Cima Volcanic Field, whereas the deeper and hotter mantle is depleted and relatively young (T= 970-1100°C, εNd = +5.7 to +16, T_{DM} < 1Ga), and similarly to the Western Mojave basalt sources, is likely to be of Pacific (Farallon) origin.

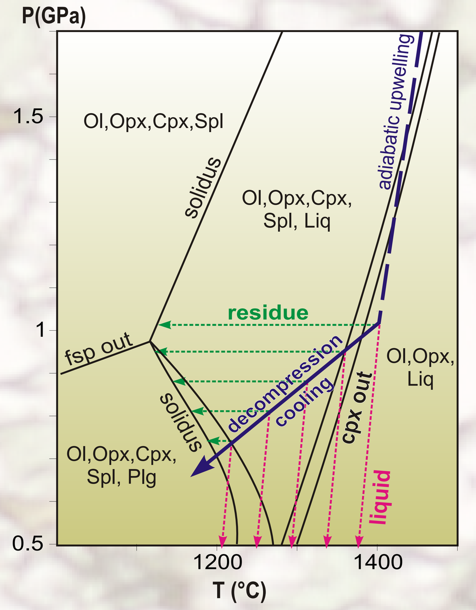
The recurrence of compositional trends may be best explained by flat subduction-related tectonic imbrication.

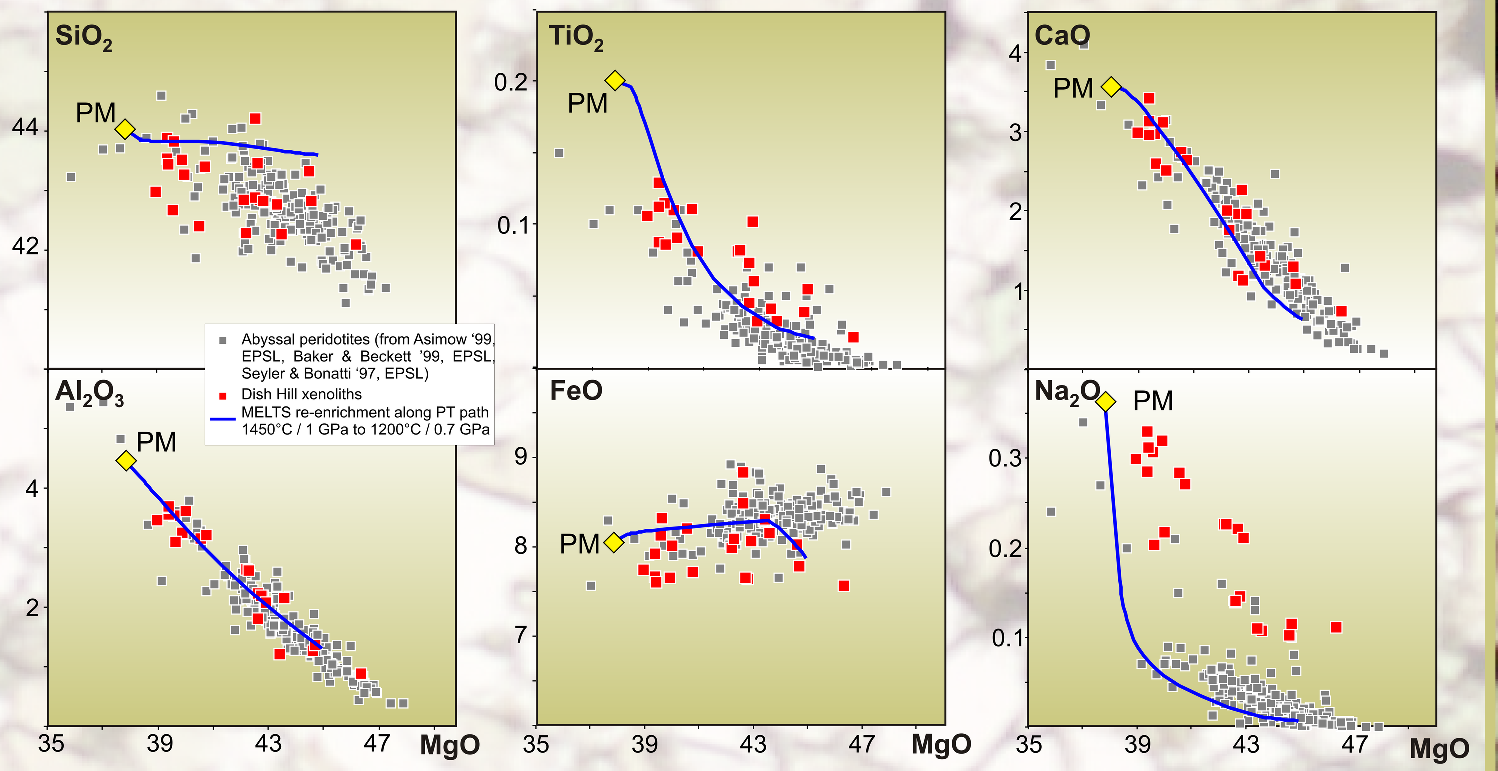
Our results 1) suggest that much of the Miocene lithospheric architecture of the Mojave Desert had been preserved without noticeable changes until Holocene, 2) corroborate the idea that no significant post-Miocene extension has shaped the Mojave Desert, and 3) may place important constraints on thermal evolution and dynamics of the Farallon plate.

(Cartoon cross section adapted from Miller et al 2000, GSA)

4. Implications for understanding the compositional layering of oceanic mantle lithosphere

The downwards depleted trends observed in the medium- and high-T xenolith suites from Dish Hill cannot be easily reconciled with the general view that mantle lithosphere formed at mid-ocean ridges (MOR) are largely upwards depleted due to progressive melt extraction from the uprising asthenosphere. Employing the *adiabat_1ph* software [Smith & Asimow, G^3] and the MELTS thermodynamic database [Ghiorso & Sack, 1995, CMP] we tested the possibility to develop limited-scale upwards reenrichment trends in MOR residual peridotites. Assuming that abyssal peridotites form by combined batch and fractional melting processes [e.g. Asimow, 1999, EPSL], we calculated the compositions of solid residua resulted by adiabatic batch melting until Cpx exhaustion (*F ~ 20%*), followed by limited fractional melting along polybaric cooling paths. Our results indicate that low dP/dT polybaric cooling paths may explain the composition-depth trends of the Dish Hill medium- and high-T peridotites in terms of most major elements, except Si and Na. Whereas SiO_2 discrepancies rather may be related to the employed thermodynamic database, Na_2O differences are more likely of natural origin, and need further considerations.





5. Summary

- Mantle xenolith suite from Dish Hill reveal juxtaposition of old, isotopically enriched North American lithosphere and younger, isotopically depleted Farallon slab beneath the central Mojave Desert during the Late Pleistocene-Holocene. This conclusion constrains geodynamic models of the Southwestern United States .
- Compositional trends in medium- and high-T xenoliths suggest subduction induced tectonic imbrication in the Farallon slab.
- Adiabatic batch melting combined with limited fractional melting along polybaric cooling paths in MOR environment may explain the top-to-bottom depletion trend observed in the Dish Hill peridotites.

ACKNOWLEDGEMENTS

P.L. gratefully acknowledges discussions and constructive suggestions by Paul Asimow. This research was supported by the Caltech Tectonics Observatory.