# Impact of metasomatism on Colorado Plateau Lower Crustal density: Insights from Xenoliths from the Moses Rock and Mule Ear Diatremes, Navajo Volcanic Field

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National Science Foundation's Geodetic Facility for the Advancement of Geoscience

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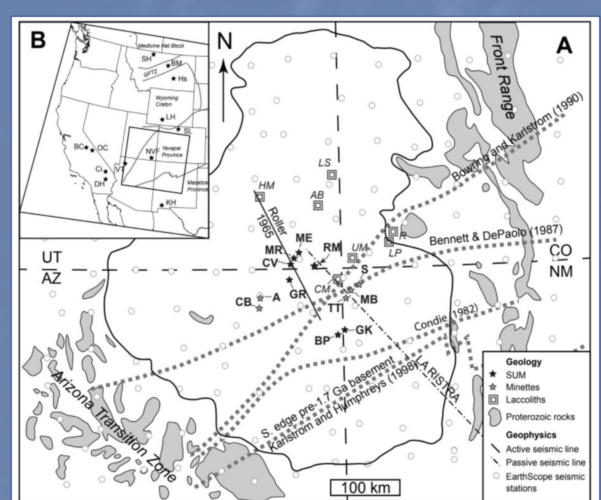
## Overview of Purpose

The Colorado Plateau was formed in a **subduction event** within the Laramide Orogeny roughly 80 mya.
There is evidence for **lithospheric hydration**.

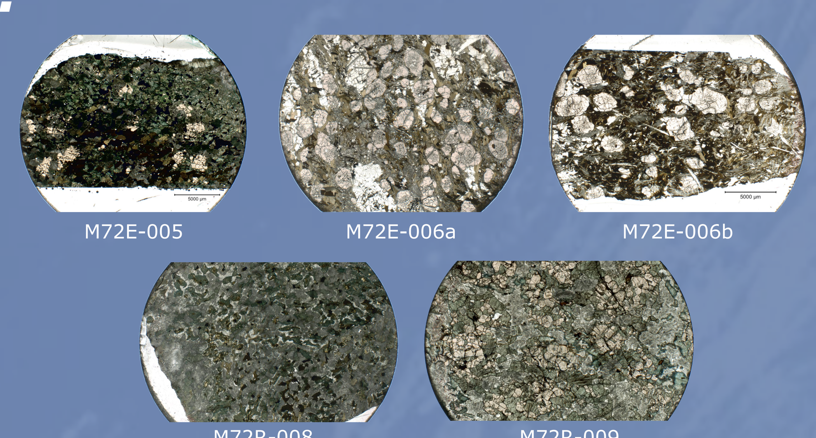



There are **2 km of surface uplift** which **cannot** be explained through the **shortening of the Laramide Orogeny** alone.

*Focus: Use lower-crustal **xenoliths** to **compare densities** calculated from **pre- and post-hydration** assemblages.*

## Methods

***Samples:***




1. TESCAN Integrated Mineral Analyzer (TIMA)
   Provides quantitative mineralogical and textural data on the basis of automated point counting
2. Electron Probe MicroAnalysis (EPMA)
   Determines composition on a small spot of a thin section with a high-energy beam
3. Aber and Hacker 2016 Calculation Model
   Calculates Density, Temperature, and Pressure
4. Density Models
   Pre- and Post- hydration models

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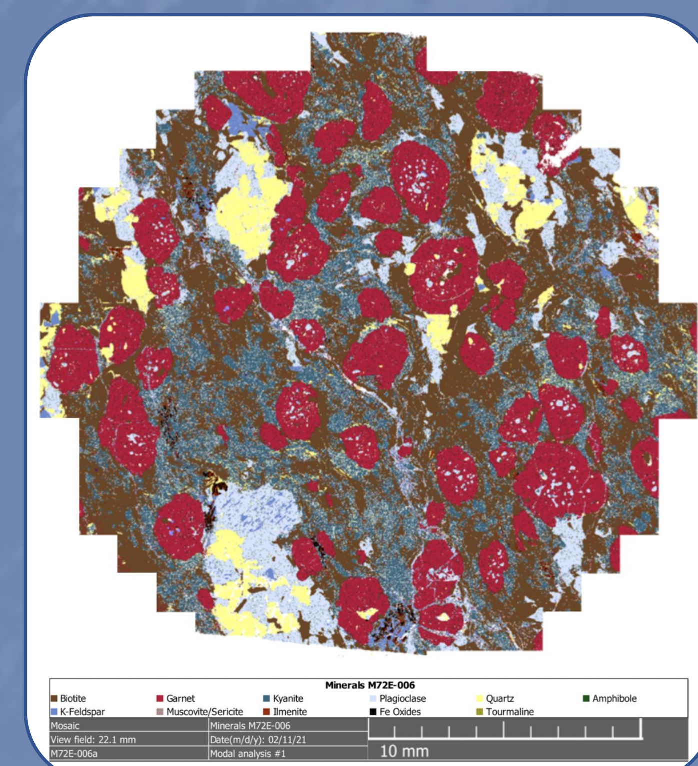
## Results

### TIMA and EPMA for M72E-006a

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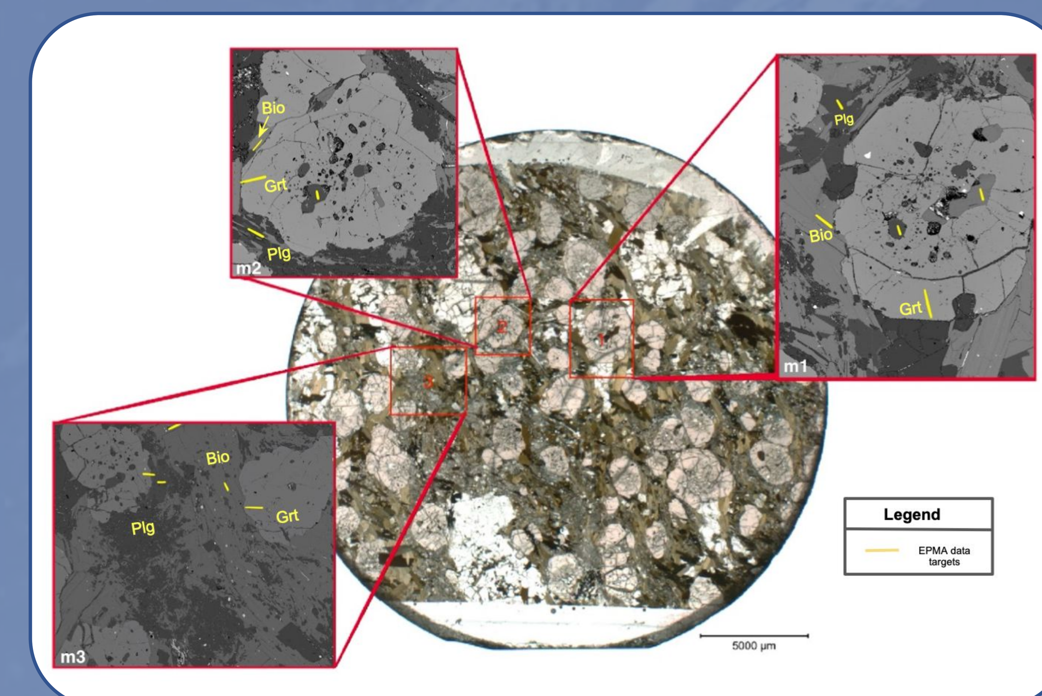
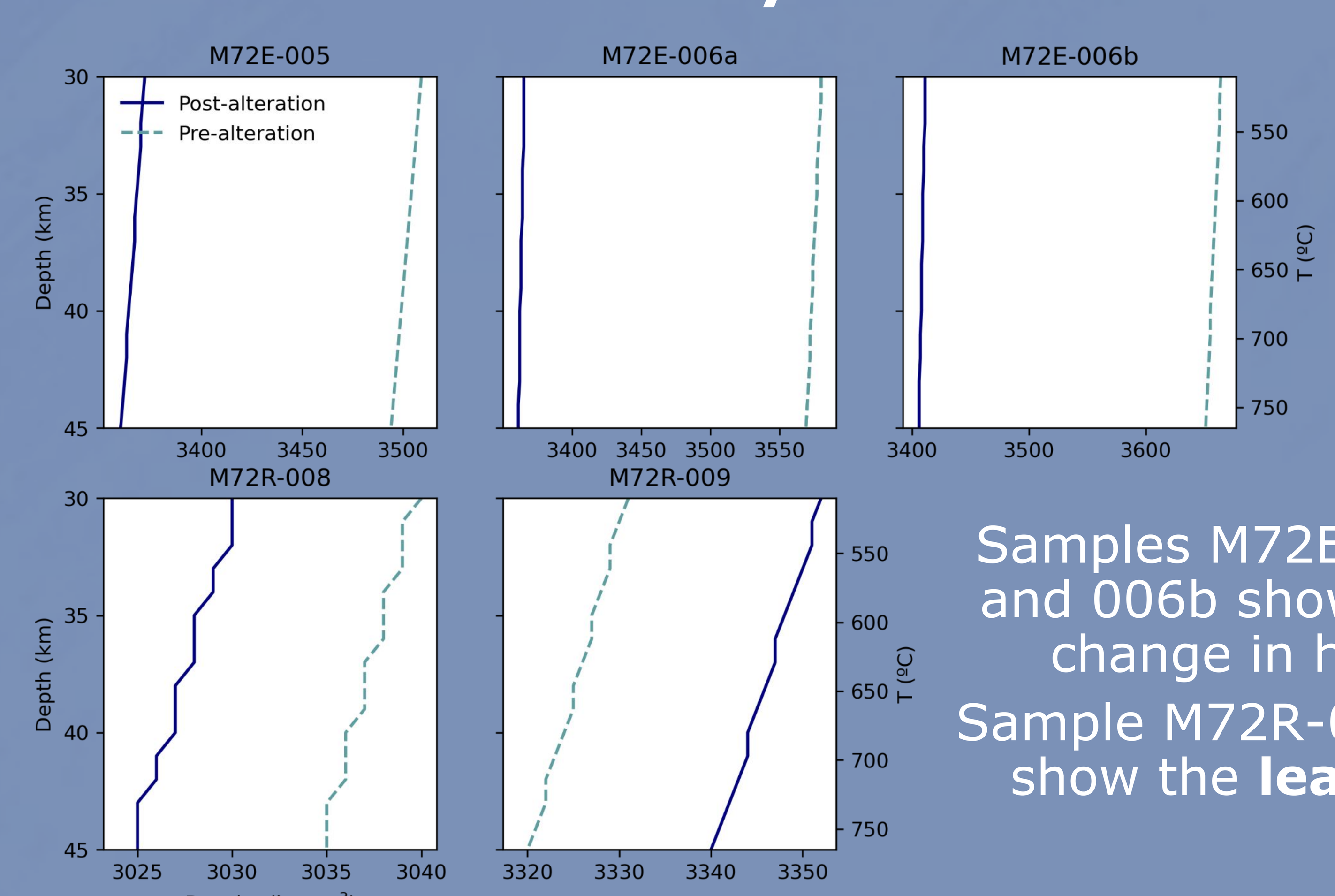



### Modal Mineralogies (A&H 2016)

Modal fractions of hydrous minerals were **redistributed into anhydrous phases** based on chemistry and plausible retrograde reactions

| Mineral | | | Post-Alteration | | | | | Pre-alteration | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Abbr** | **Name** | **Formula** | **M72E-005** | **M72E-006a** | **M72E-006b** | **M72R-008** | **M72R-009** | **M72E-005** | **M72E-006a** | **M72E-006b** | **M72R-008** | **M72R-009** |
| **qz** | quartz | $SiO_2$ | | 5.4 | 0.6 | | 0.1 | | 5.4 | 0.6 | | 0.1 |
| **hAb** | albite | $NaAlSi_3O_8$ | 6.7 | 6.3 | 3.8 | 35.0 | 22.9 | 9.0 | 6.3 | 3.8 | 29.0 | 26.0 |
| **an** | anorthite | $CaAl_2Si_2O_8$ | 0.5 | 3.1 | 1.9 | 1.7 | 0.8 | 6.2 | 3.1 | 1.9 | 29.4 | 3.1 |
| **or** | orthoclase | $KAlSi_3O_8$ | 0.0 | 1.8 | 0.4 | 0.1 | 0.0 | 3.9 | 1.8 | 0.4 | 1.0 | 0.2 |
| **alm** | almandine | $Fe_3Al_2Si_3O_{12}$ | 5.5 | 17.9 | 13.9 | | 15.1 | 5.6 | 20.5 | 17.2 | | 16.9 |
| **gr** | grossular | $Ca_3Al_2Si_3O_{12}$ | 1.8 | 1.1 | 0.9 | | 4.4 | 2.2 | 1.1 | 0.9 | | 5.8 |
| **py** | pyrope | $Mg_3Al_2Si_3O_{12}$ | 1.9 | 5.4 | 3.7 | | 8.4 | 1.9 | 8.6 | 7.1 | | 9.5 |
| **en** | enstatite | $Mg_2Si_2O_6$ | | | | | 5.1 | 5.0 | 15.8 | 16.9 | 4.0 | 6.2 |
| **fs** | ferrosilite | $Fe_2Si_2O_6$ | | | | | 1.5 | 4.5 | 12.4 | 15.1 | 10.0 | 1.6 |
| **di** | diopside | $CaMgSi_2O_6$ | | | | | 18.9 | 23.1 | | | 9.5 | 18.9 |
| **hed** | hedenbergite | $CaFeSi_2O_6$ | | | | | 5.5 | 20.1 | | | 10.0 | 5.5 |
| **fgl** | ferroglaucophane | $Na_2Fe_3Al_2Si_8O_{22}(OH)_2$ | | | | | 1.7 | | | | | |
| **tr** | tremolite | $Ca_2Mg_5Si_8O_{22}(OH)_2$ | 9.4 | | | | 2.9 | | | | | |
| **fact** | ferroactinolite | $Ca_2Fe_5Si_8O_{22}(OH)_2$ | 15.6 | | | 8.8 | | | | | | |
| **parg** | pargasite | $NaCa_2Mg_4Al_3Si_6O_{22}(OH)_2$ | 12.9 | | | 3.6 | | | | | | |
| **hb** | hornblende | $Ca_2Mg_2Fe_2Al_3Si_6O_{22}(OH)_2$ | 6.2 | | | 20.7 | | | | | | |
| **anth** | anthophyllite | $Mg_7Si_8O_{22}(OH)_2$ | | | | | 1.2 | | | | | |
| **phl** | phlogopite | $KMg_3AlSi_3O_{10}(OH)_2$ | | 18.9 | 20.3 | 3.4 | 0.6 | | | | | |
| **ann** | annite | $KFe_3AlSi_3O_{10}(OH)_2$ | | 14.9 | 18.1 | 4.7 | 0.2 | | | | | |
| **mu** | muscovite | $KAl_3Si_3O_{10}(OH)_2$ | 0.4 | 1.2 | 1.4 | | | | | | | |
| **clin** | clinochlore | $Mg_5Al_2Si_3O_{10}(OH)_8$ | 5.7 | | | 0.1 | | | | | | |
| **daph** | daphnite | $Fe_5Al_2Si_3O_{10}(OH)_8$ | 3.8 | 0.1 | 0.3 | 0.1 | 0.1 | | | | | |
| **cz** | clinozoisite | $Ca_2Al_3Si_3O_{12}(OH)$ | 4.6 | | | 7.1 | 2.3 | | | | | |
| **ep** | epidote | $Ca_2FeAl_2Si_3O_{12}(OH)$ | 8.7 | | | 8.2 | 2.0 | | | | | |
| **ky** | kyanite | $Al_2SiO_5$ | | 15.8 | 25.8 | | | | 17.0 | 27.2 | | |
| **mt** | magnetite | $Fe_3O_4$ | 4.6 | 0.4 | 0.2 | 0.0 | 0.0 | 7.1 | 0.4 | 0.2 | 0.0 | 0.0 |
| **ilm** | ilmenite | $FeTiO_3$ | 2.1 | 0.6 | 0.4 | 1.2 | 0.1 | 2.1 | 0.6 | 0.4 | 1.7 | 0.1 |
| **rut** | rutile | $TiO_2$ | 1.5 | | | | 0.3 | 1.5 | | | | 0.3 |
| **ttn** | titanite | $CaTiSiO_5$ | | | | 0.0 | | | | | 0.0 | |
| **cc** | calcite | $CaCO_3$ | 0.6 | | | 0.2 | | 0.2 | | | 0.3 | |
| | **Total** | | **92.3** | **92.9** | **91.7** | **94.9** | **94.2** | **92.4** | **92.9** | **91.7** | **94.9** | **94.2** |

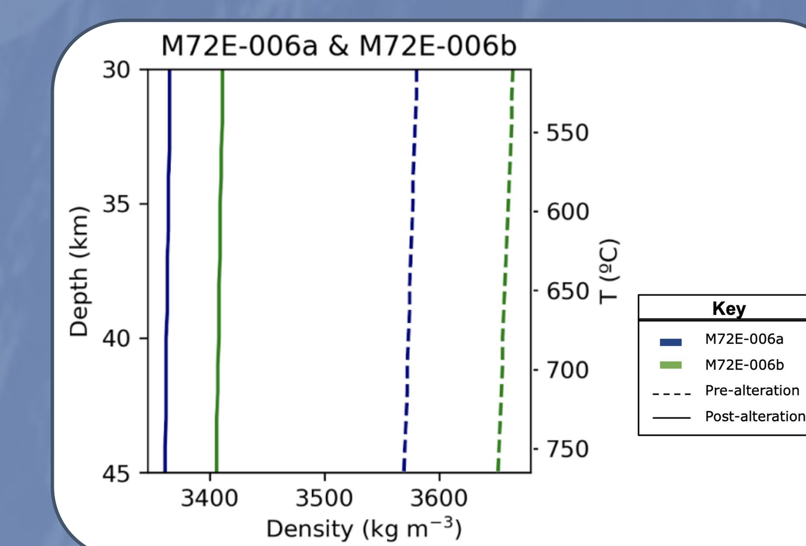
### Pre- and Post- hydration Densities




Samples M72E-005, 006a and 006b show the **most** change in hydration
Sample M72R-008 and 009 show the **least** change

## Discussion/Conclusion

1. Calculated pre- alterations portray **heavier densities** compared to post- alteration assemblages due to lack of hydration
2. Samples M72E-006a and 006b come from the **same xenolith** but have **different calculated densities**




3. **Hydrous minerals** are **less dense** than inferred anhydrous precursor minerals, leading to **lower post-alteration densities**
3. The excess 2 km surface uplift can **partially** be **explained** through **by hydration** of the lower crust
4. **Big things** often have **small beginnings**

## Acknowledgments

I would like to acknowledge that our research was conducted on the traditional territory of Pueblos, Ndee/Nnēē: (Western Apache).

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