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Supporting Information for "Lower Crustal Composition in the Basin and Range"

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Additional Supporting Information (Files uploaded separately)

1. Geochemical Samples

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1. Perple_X Modeling Parameters

Parameter - *Value* - Justification

Thermodynamic data file - *Hpha02ver.dat: Holland and Powell thermodynamic database, augmented by Hacker and Abers (2004)* - Holland and Powell (2004) presents a self-consistent thermodynamic database. Hpha02ver is similar to hp02ver but is augmented by Hacker and Abers (2004) to be consistent with the α - β quartz transition. Another option, Hp11ver.dat, does not include shear moduli and thus cannot be used to calculate Vs. The Stx11ver.dat database uses the Stixrude and Lithgow-Bertelloni (2011) method for calculating elastic moduli, but only considers major mantle phases.

Solution models - *N/A* - All default solution models were included.

Pressure - *1,500 - 15,000 bars (0.15 - 1.5 GPa)* - This range translates to depths from about 5km to 50km, a range that encompasses the granulite stability field and expected deep crustal depths.

Temperature - *300 - 1300 K (27 - 1,027°C)* - 800 K - 1300 K encompasses the stability field for granulite. 300 K - 800 K covers all possibilities from near-surface temperatures to the granulite wet solidus. Granulites existing in this range would be at thermodynamic disequilibrium, but retrograde metamorphosis is unlikely. Granulite facies metamorphosis is marked by the dehydration of hydrous minerals. Rehydration is difficult, making rehydration unlikely to occur (Semprich & Simon, 2014).

Volatiles - *0 wt.%* - Granulite is characterized by the dehydration of hydrous minerals.

2. Suggested Updates to CRUST 1.0

High resolution, local crustal models inform their global counterparts. A mafic overall lower crustal composition, as constrained by Vs, encouragingly agrees with local petrological studies of the Basin and Range (Hanchar et al., 1994; Chen & Arculus, 1995; Dodge et al., 1986; Kempton et al., 1990; McGuire, 1994). The average compositions of all three sub-provinces of the southwestern United States agree with a R. Rudnick and Gao (2014) global lower crustal model within uncertainty. The lower crust, though, might more accurately be considered a gradient of compositions, as many of its physical properties, including density, velocity, and rheology, differ between its mafic base and intermediate to intermediate-mafic top (R. L. Rudnick & Fountain, 1995; Shinevar et al., 2018). While such details may seem trivial on the global scale, they can contribute significantly to interpretations of continental crust formation processes (Hacker et al., 2015), heat producing element distribution (Hacker et al., 2015; Huang et al., 2013; Artemieva et al., 2017), and deep lithosphere earthquakes (Jackson, 2002; McKenzie et al., 2000).

Global model refinement is not reserved for compositional models only; regional analyses can also augment geophysical models. The CRUST family (Laske et al., 2013) of global models and their derivatives predict anomalously slow seismic velocities and low densities for the entirety of the Basin and Range. Their Vp and Vs velocities of 6.6 and 3.6 km/s, respectively, imply a lower crust that is felsic to intermediate. In contradiction, regional velocity models (Parsons et al., 1995; Olugboji et al., 2017; Shen et al., 2013), along with our results, indicate the Basin and Range has fast, dense lower crust. Figures S1 - S3 show that the Basin and Range is more similar to surrounding tectonic provinces than current models suggest. A simple update in CRUST's classification of the Basin and Range from "extended crust" to "fast extended crust" (lower crust Vp = 7.0 km/s, Vs = 3.82 km/s, density = 3030 kg/m^3) would put the model in better agreement with regional-scale assessments. While this adjustment might again seem semantical, CRUST1.0 and similar models have broad impacts on various geophysical applications, including seismic tomography, lithospheric structure and thickness, mantle gravity(Herceg et al., 2015), and neutrino geoscience (Wipperfurth et al., 2019).

Figures S1- S3: reclassification of the Basin and Range from CRUST 1.0's "extended crust" to "fast extended crust", which is in closer agreement with ours and other local studies' findings.

3. Compositional Maps and Uncertainties

Figures S5 - S11

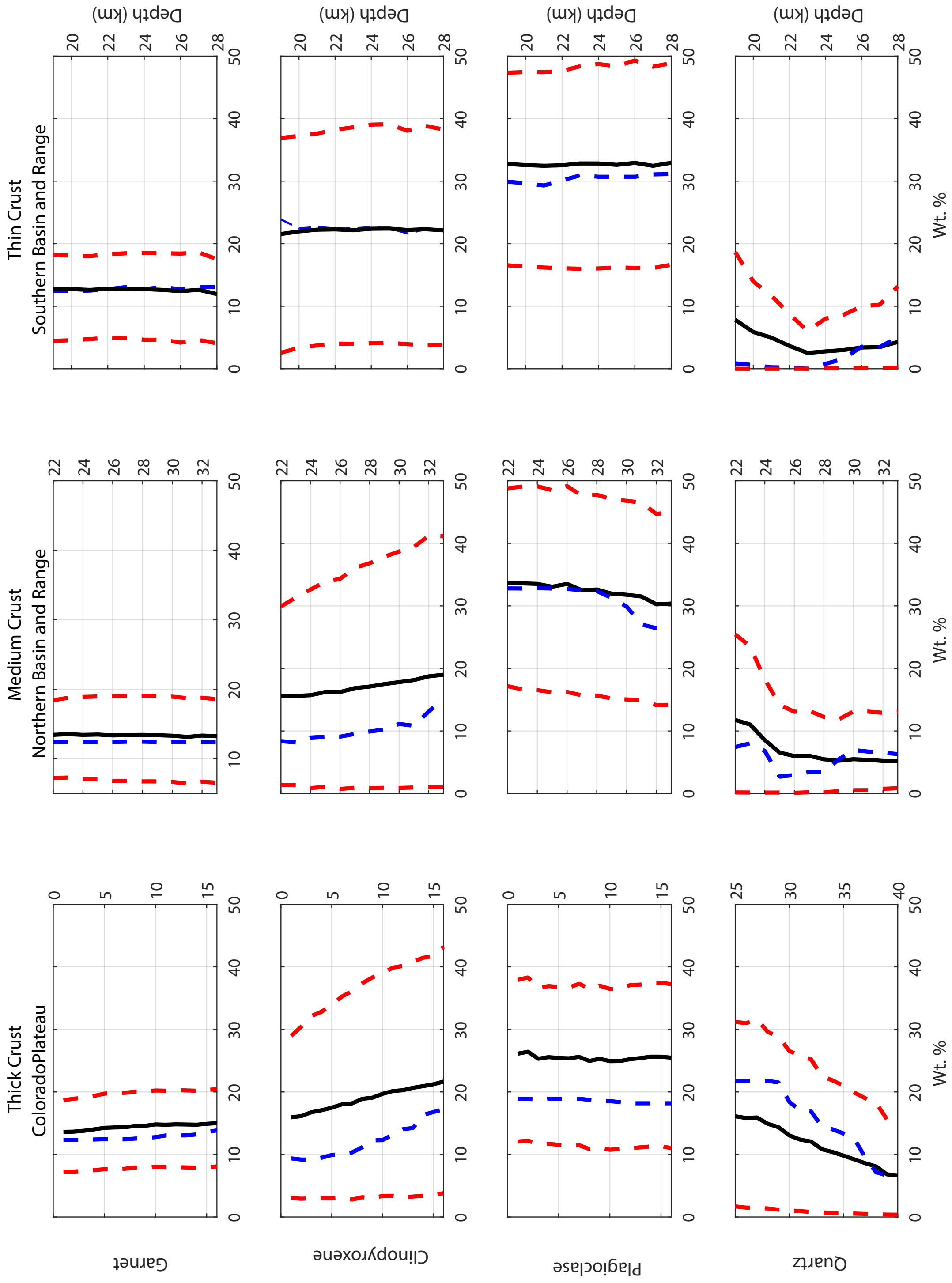

Figure S4: Changes in physical properties with depth and location control changes in predicted mineralogies. Large uncertainties mask slight increases in garnet and decreases in plagioclase feldspar. Clinopyroxene abundance increases with depth while quartz generally decreases. The thin Southern Basin and Range crust shows comparable mineralogies throughout, though could have minimal increase in quartz abundance due to the growth of *beta*-quartz.

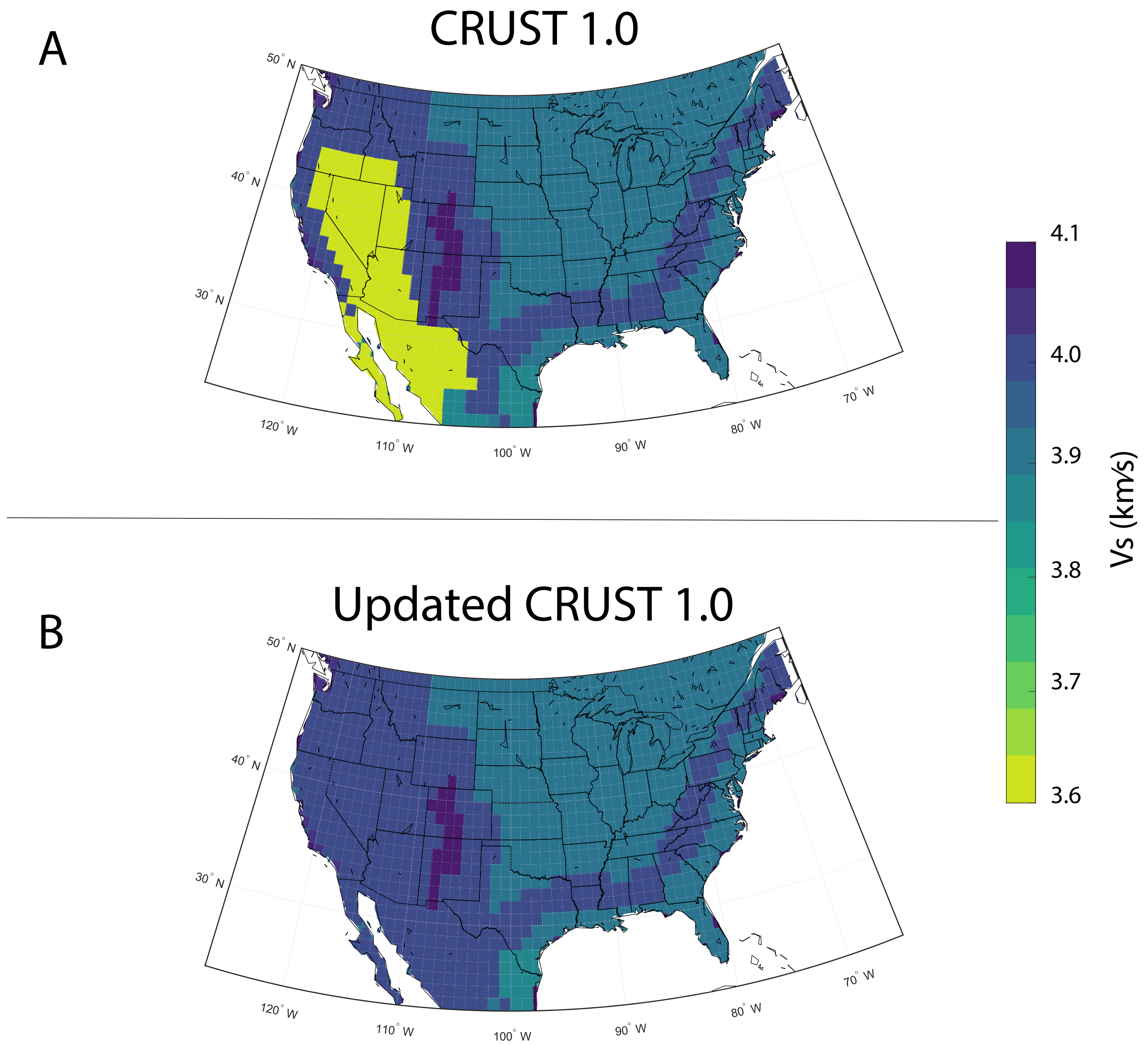

Figure S1: Shear wave velocities from CRUST 1.0 (A) updated to match our local model's Basin and Range results (B). For Figures S1 - S3: the perceptually uniform color scale shows the CRUST predicted anomaly is inconsistent with our results; (B) assigns "fast extended crust" values to all extended crust in the western United States and Mexico.

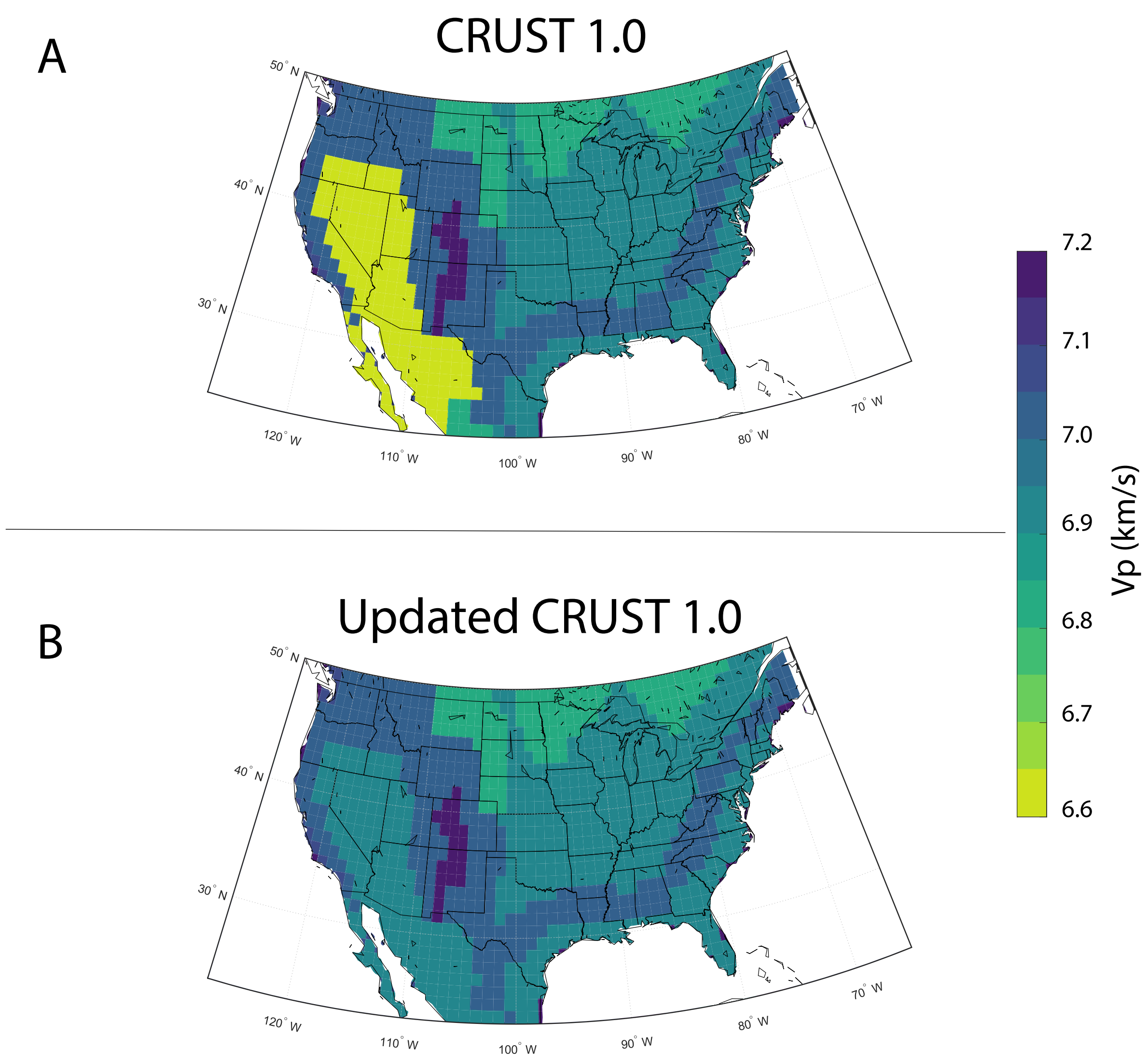

Figure S2: Compressional wave velocities from CRUST 1.0 (A) updated to match our local model's Basin and Range results (B).

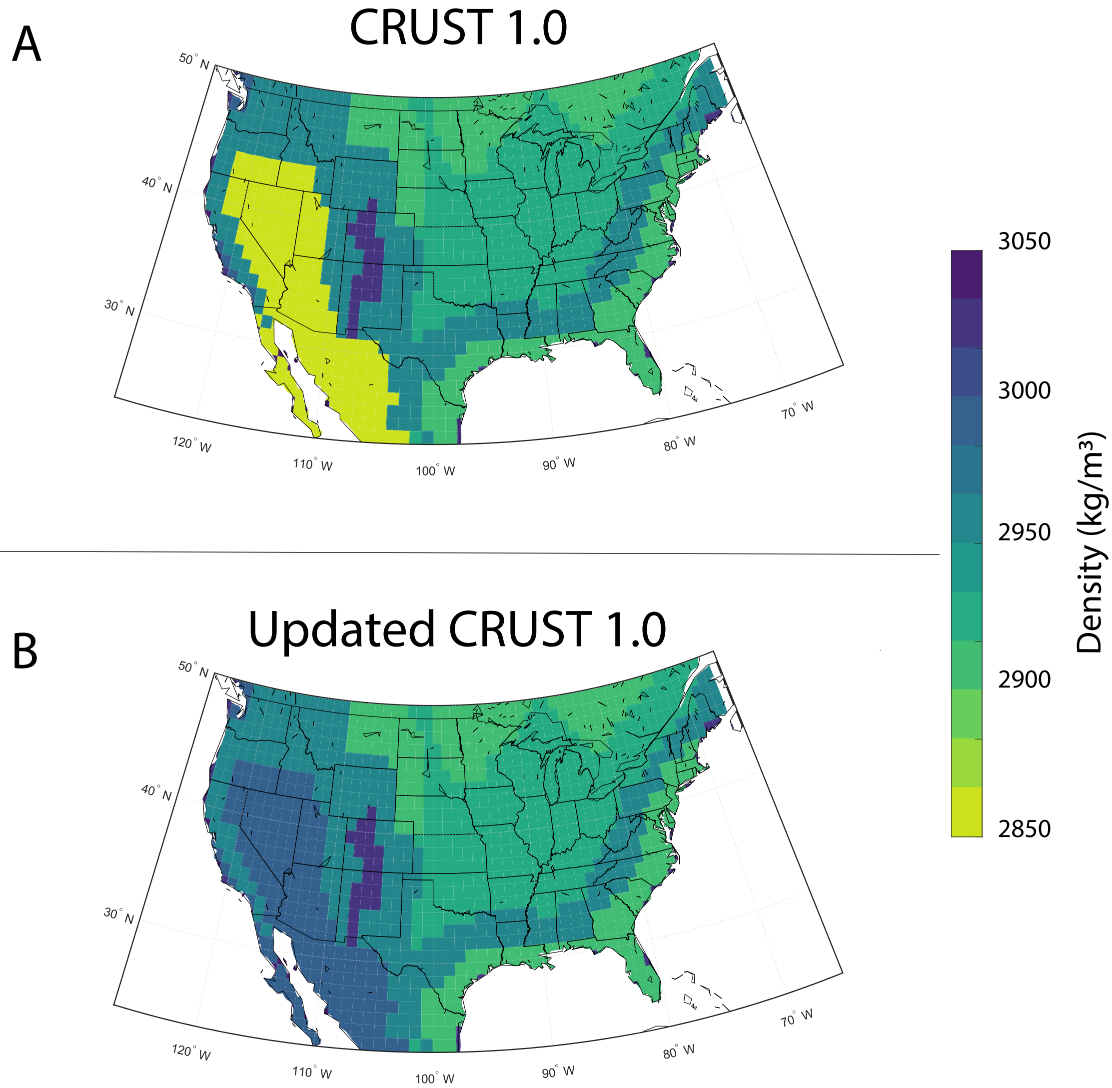

Figure S3: Densities from CRUST 1.0 (A) updated to match our local model's Basin and Range results (B).

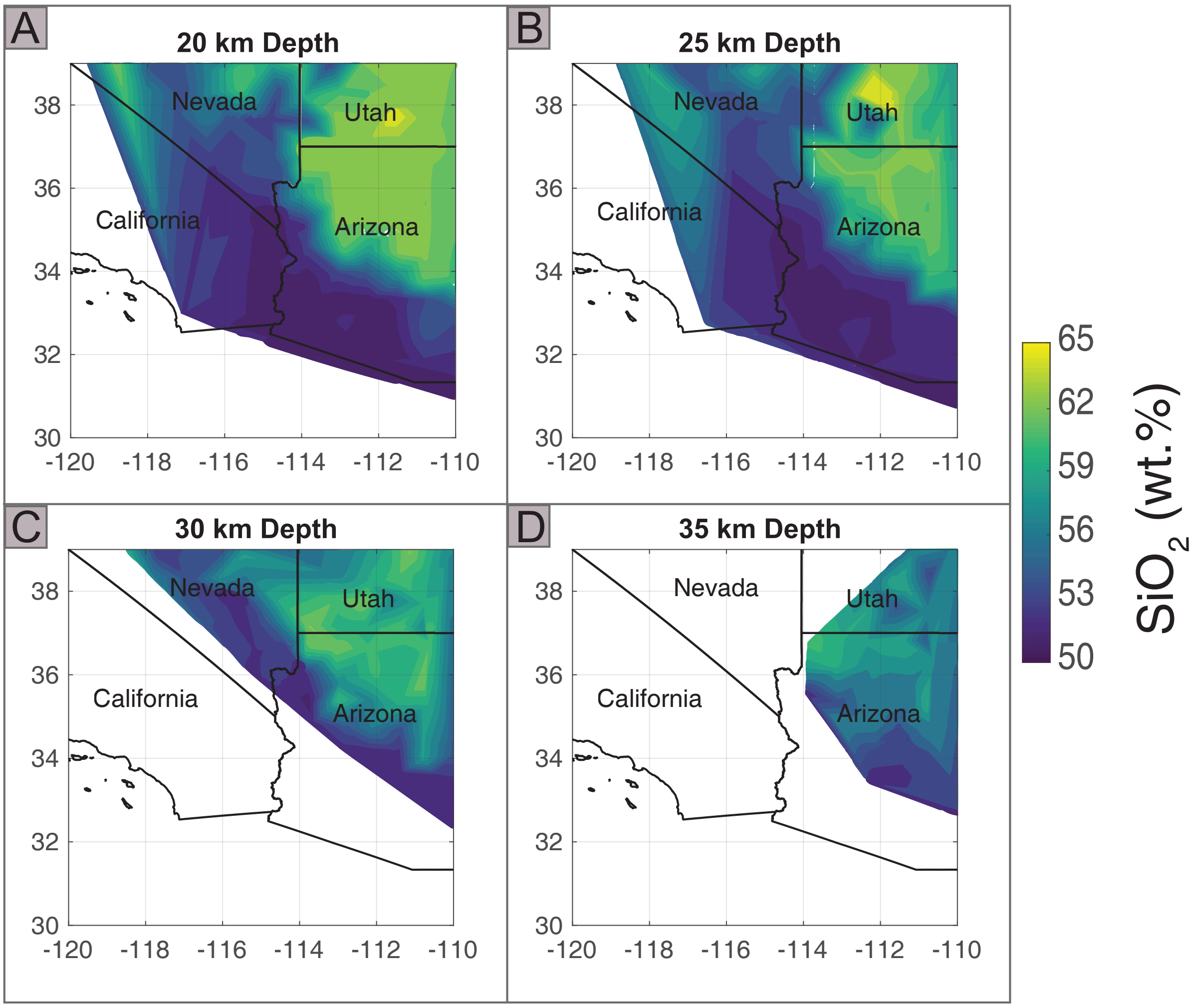

Figure S5: (From main text) Variability in median SiO_2 abundance in the southwestern United States tracks the Colorado Plateau (high SiO_2), Great Basin (medium SiO_2), and Southern Basin and Range (low SiO_2). SiO_2 abundance overall decreases with increasing depth (A - D). Color scale indicates wt.% SiO_2. Mantle compositions are not shown in this figure, and therefore deeper profiles (e.g. C - D) show only those regions which have greater crustal thickness.

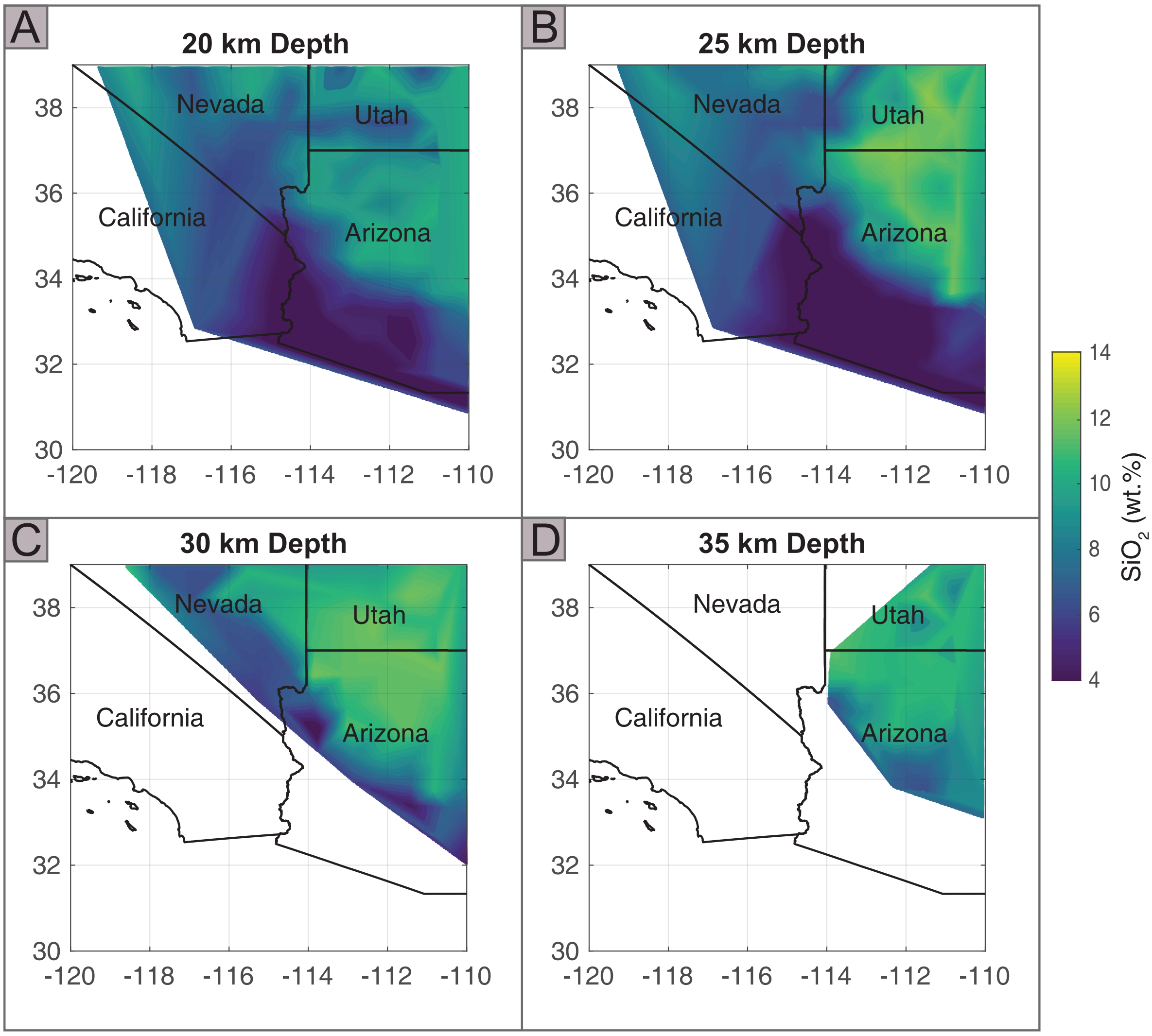

Figure S6: Uncertainty in wt.% associated with our SiO_2 calculations. Uncertainty is calculated as $\frac{1}{2}$ the inter-quartile range at various depths. Uncertainty is lowest in the Southern Basin and Range and remains relatively consistent with depth.

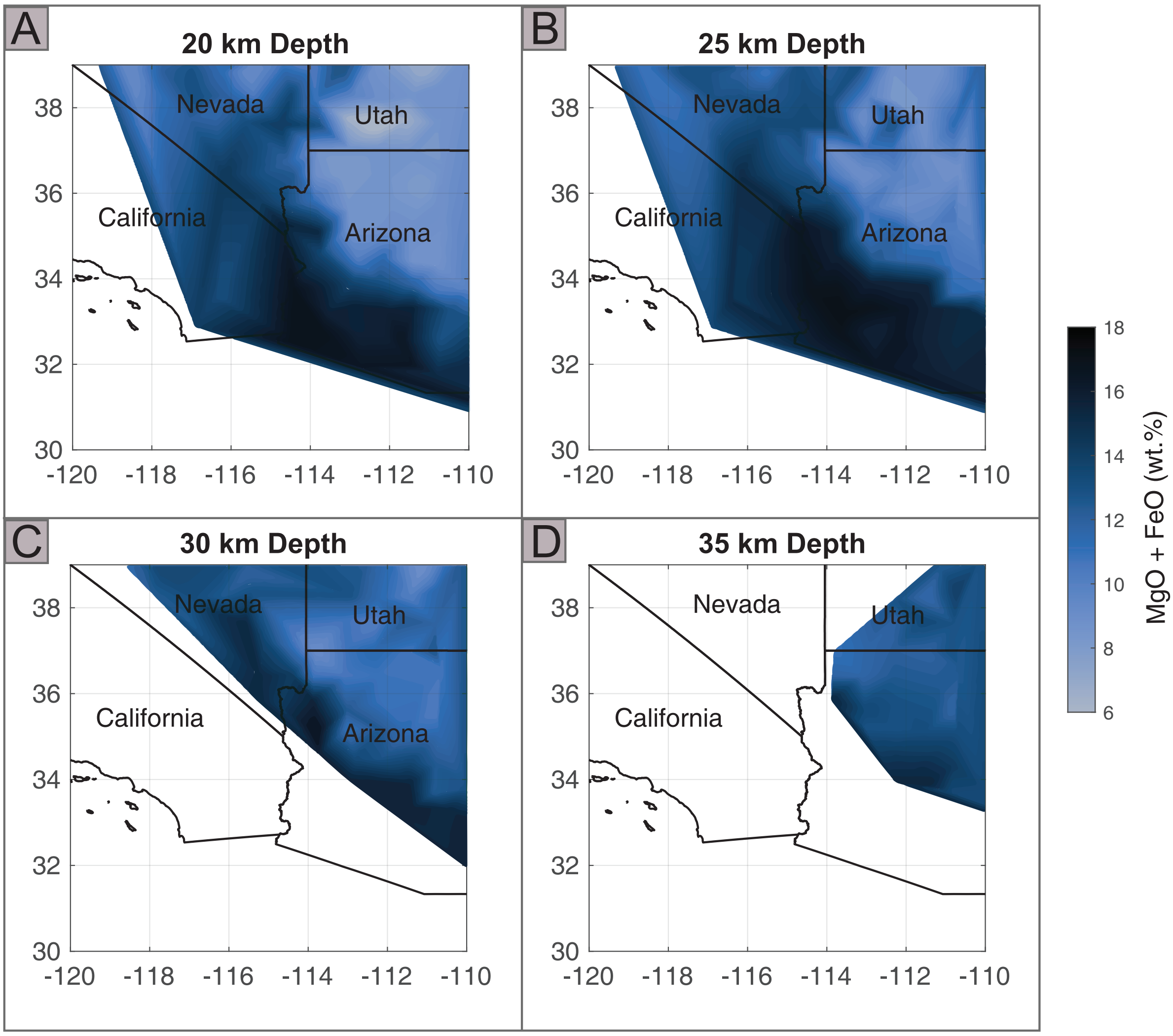

Figure S7: Variations in median MgO + FeO abundance across the Basin and Range and Colorado Plateau. Where SiO_2 abundance in Figure S5 decreased, amount of mafics increases with depth. The Southern Basin and Range has a consistently high mafic content while the Colorado Plateau is more intermediate.

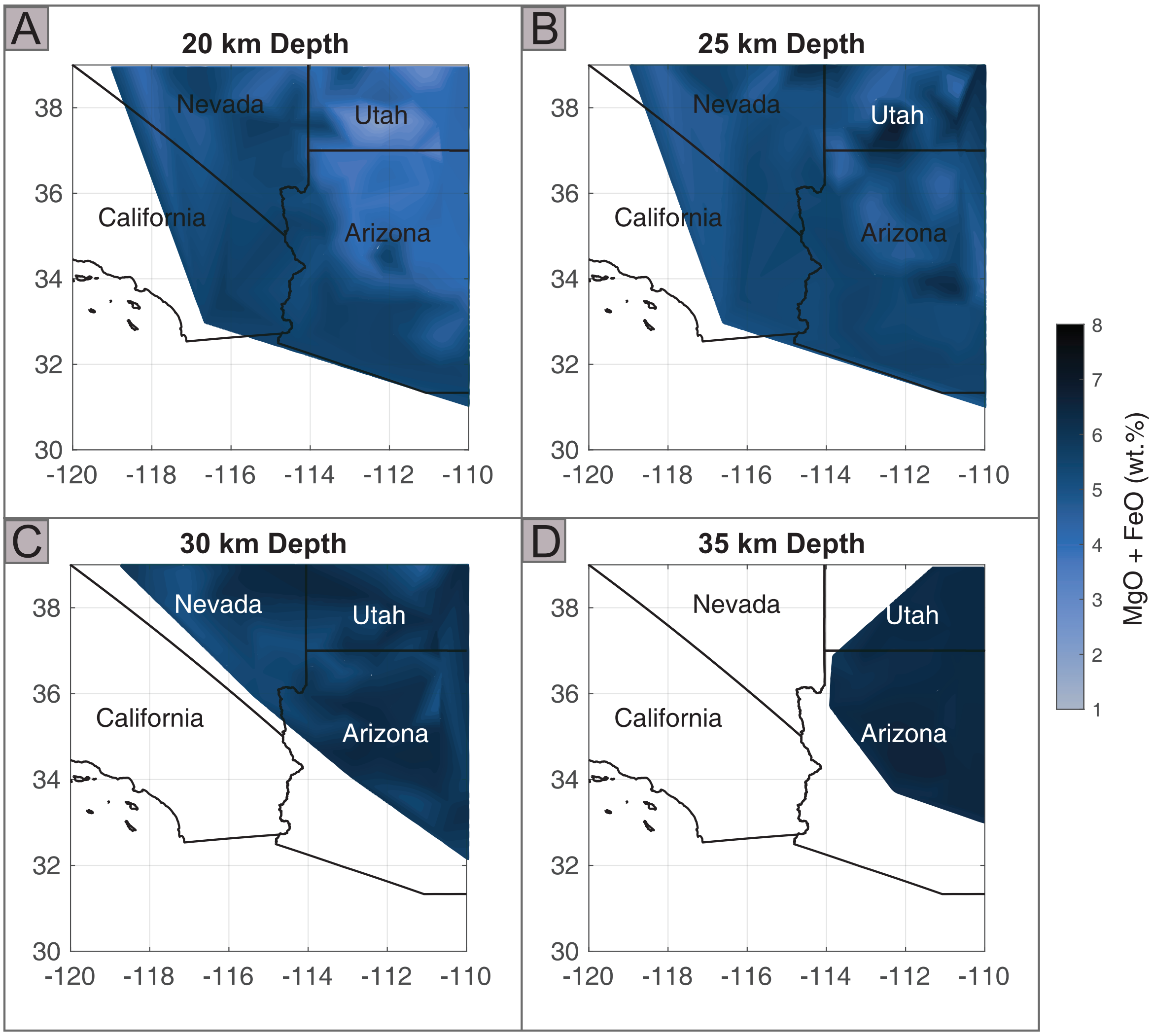

Figure S8: Uncertainty in wt.% associated with our MgO + FeO calculations. Uncertainty is calculated as $\frac{1}{2}$ the inter-quartile range at various depths, and increases by a few wt.% with increasing depth.

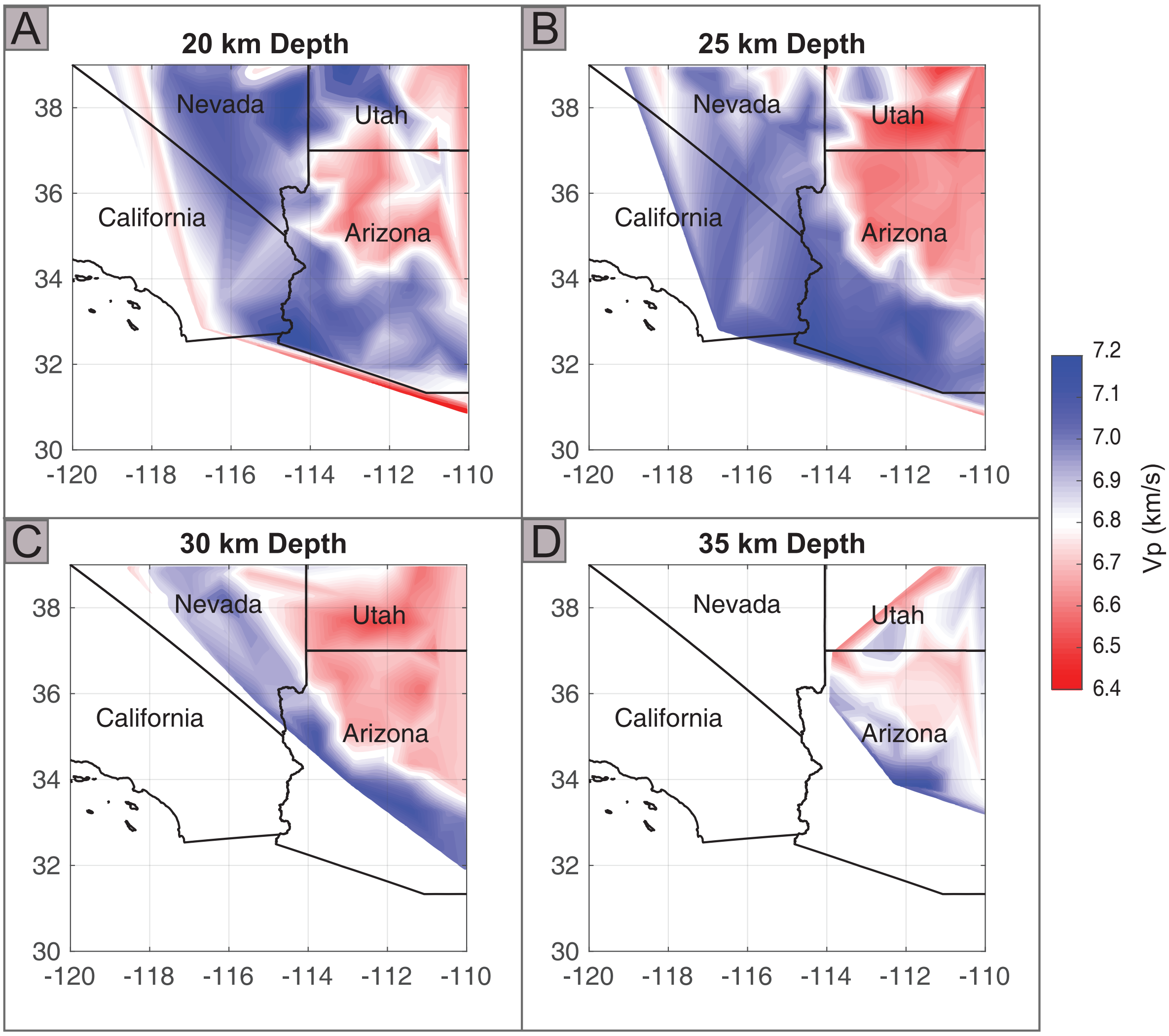

Figure S9: Median Vp calculated from the joint geochemical-geophysical model. Original Vp's were calculated in Perple_X. The Colorado Plateau is clearly visible as a slower Vp region to the east.

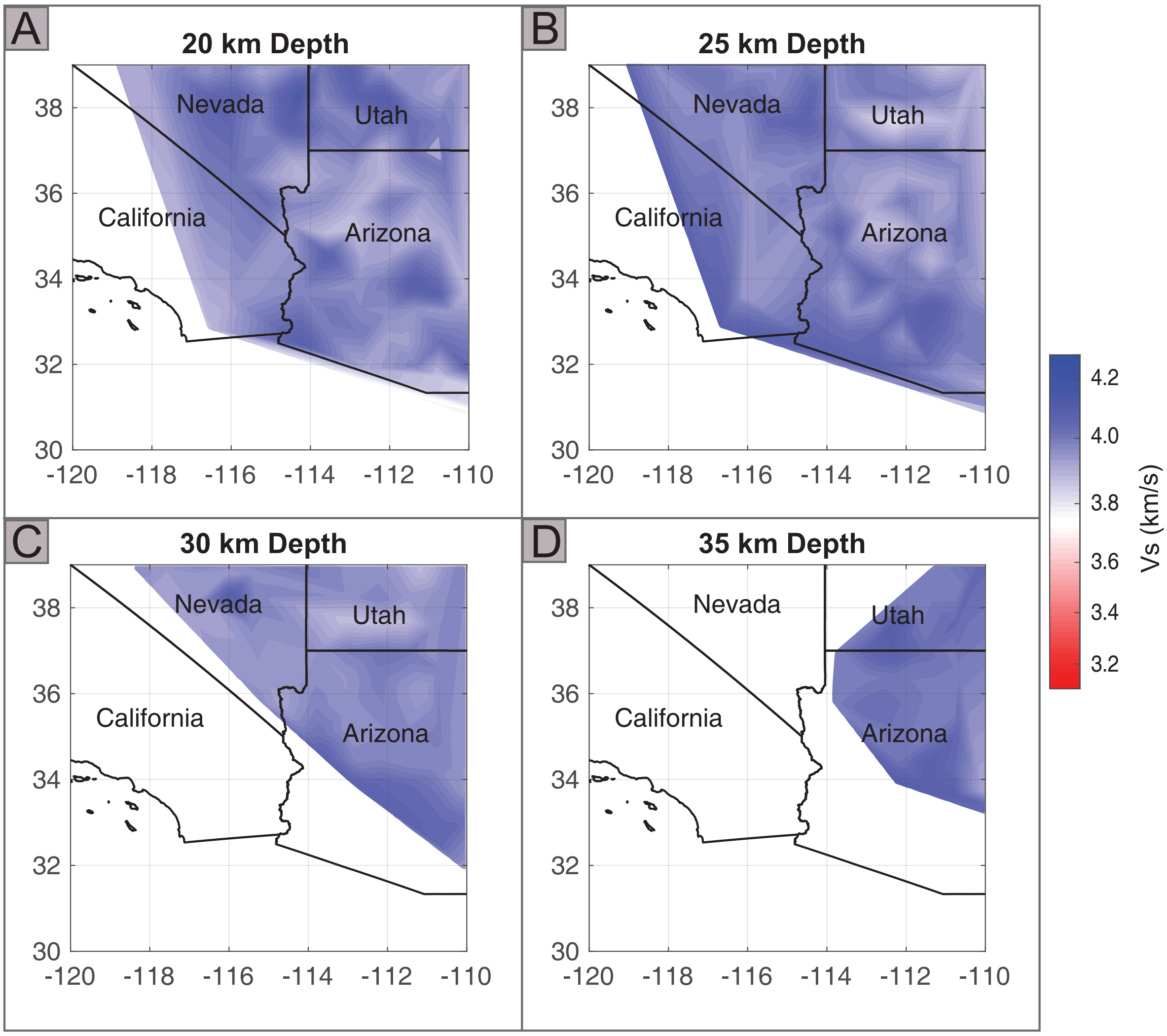

Figure S10: Joint model selections of median Vs. The geochemical data favor faster Vs solutions and therefore weight the model.

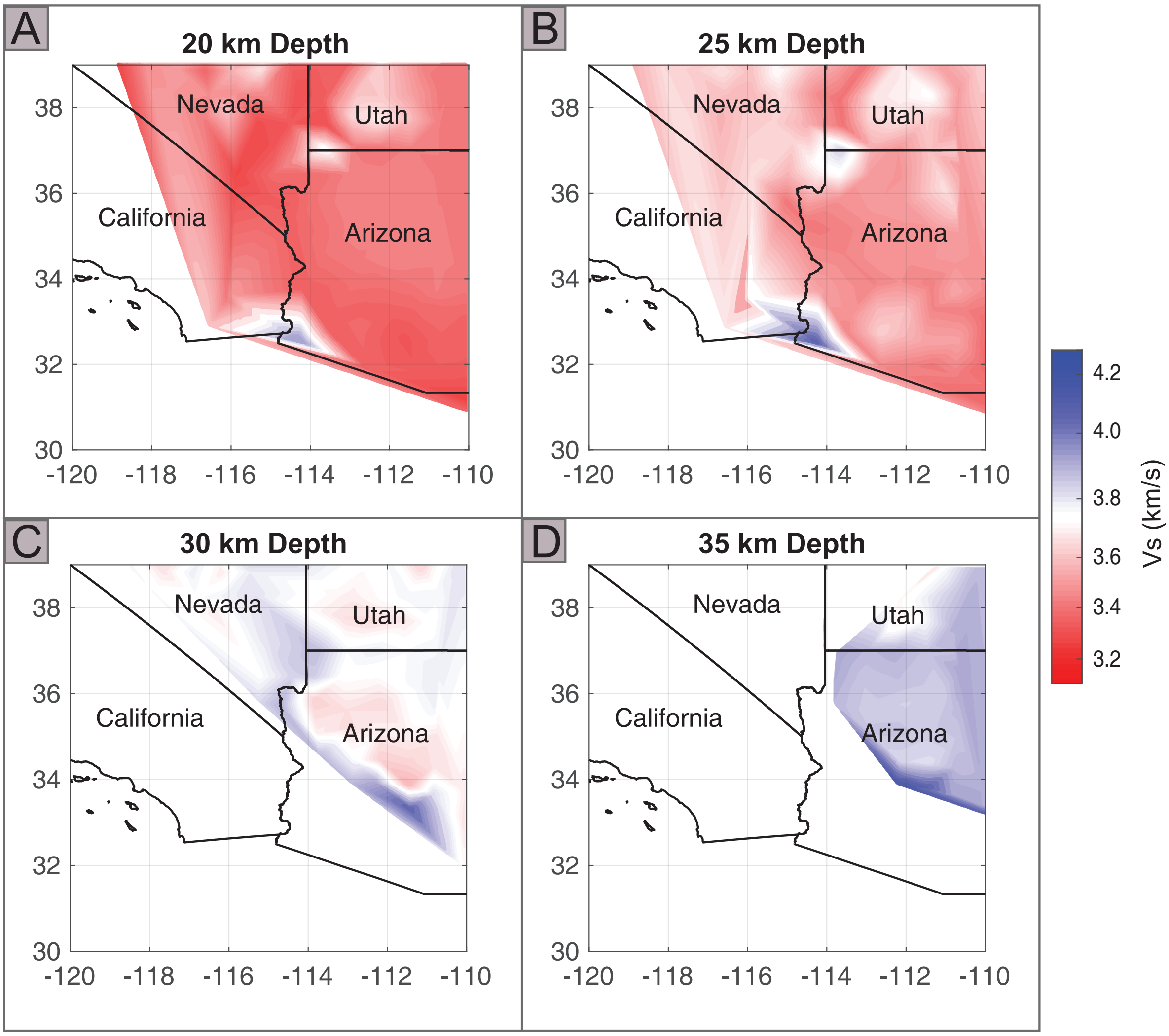

Figure S11: Median Vs from inversion of Earthscope USArray seismic data at various depths. Vs increases noticeably with increasing depth.

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