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Thermal Evidence of Flat-Slab Subduction Perturbations in the Western US

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Abstract

The Laramide Orogeny, a late Cretaceous mountain building event in the western United States, has been postulated to result from flat-slab style subduction of the Farallon plate[1,2,3]. Possible consequences of flat-slab style subduction on elevation, tectonism and volcanism associated with expected changes in temperature and hydration state of the mantle in the western U.S. has been of considerable interest[x1]. However, the impact of flat-slab subduction on modern mantle temperature, water and tectonic stability remains poorly-understood. Here we show that thermal perturbation by Farallon flat slab subduction is still evident today in Moho temperatures of the Rocky Mountain and Great Plains regions of the U.S. Measurements of temperature in the uppermost mantle from tomographic P-wave velocity images[4] are compared to models of surface heat flow measurements assuming steady-state lithospheric thermal transfer and reasonable rock thermal properties. Misfit between modeled and measured Moho temperature indicates a violation of the modeling assumptions, likely dominated by transient perturbations on timescales less than the ~100 Myr required for a conductive thermal pulse to traverse the lithosphere. Misfit is dominated by anomalously low measurements in regions deformed by thick-skin tectonism during the Laramide, suggesting the temperature discrepancy may reflect thermal perturbation by Farallon flat-slab subduction. Shallow subducted slab would serve both to chill the base of the lithosphere and insulate it from deeper convective heating. The measurements indicate perturbation of mantle lithospheric temperature to distances of more than 1800 km from the modern plate boundary, where Laramide-style tectonism was weakly expressed. These results may have significant implications for history, evolution and stability of continental lithosphere within EarthScope's USArray footprint[5].

Introduction

The subduction and subsequent removal of the proposed Laramide flat slab subducted plate dramatically impacted the geologic landscape of much of the North American Cordillera. The hypothesised removal of the plate caused the so-called "ignimbrite flare-up" of the Mid-Tertiary, and re-introduction of higher temperature mantle to the base of the lithosphere is one likely contributor to uplift of the Colorado Plateau and other Cordilleran regions[6]. Thermal perturbation of the lithosphere by shallowly-dipping subducted slab is expected to be significant because the time required to thermally equilibrate an initial slab temperatures to the ~1350°C potential temperature of asthenospheric mantle are large relative to the time required for transport to distances of order 1000 km from the trench, with final temperatures of subducted oceanic crust dependent primarily on age of the oceanic lithosphere and rate of subduction convergence[7].

Thermal modeling

Two important pieces of informational constraint here: surface heat flow and Pn-derived Moho temperature. Need to describe (at least cursorily) important features of heat transfer that determine the geotherm: radiogenic heat production in the crust, temperature dependence of thermal conductivity, advective heat transfer processes.

We modeled the geothermal gradient using data from surface heat flow, surface temperatures, radiogenic heat production in the crust, and crustal thickness measurements (Lowry et al.). To arrive at best fitting parameters for conductivity, parameters A and B were grid-searched for each map point for the western US. The values were used to calculate a geothermal gradient for each of the ~50,000 points, this geotherm was then compared against Pn wave inferred moho temperature estimates to produce an overall RMS misfit. Significant efforts were made to reduce the RMS misfit, by varying radiogenic length parameters (*lrad*), surface heat production (A_0), to minimize the RMS. These efforts were unfruitful as they eventually produced non-physical results. Therefore fixed *lrad* (14km) and mean A_0 values were used.

Numerically searched conductivity parameters (*q*) were compared to laboratory values established by Kukkonen et al[10] (See Figure 1). The mapped RMS on a A versus B parameters grid searched yielded consistent trends with lab values. Plotted conductivity parameters of various compositions follows a trend going from quartz poor (more mafic) to quartz rich (more granitic). With the admitted limitations picking a singular best fitting values of $A=.23$ and $B=5.4*10^{-4}$ creating a compositionally uniform crust.

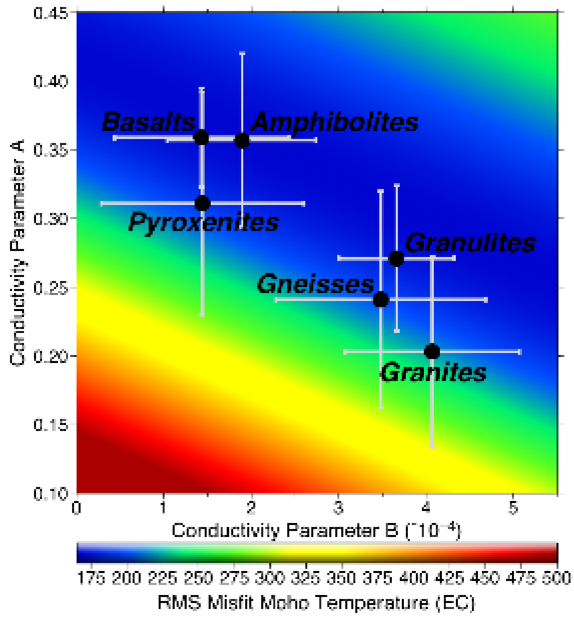

Figure 1- Numerically grid searched A and B parameters of conductivity overlayed on laboratory values determined by Kukkonen et al. Each point tested over whole of western US. Best fitting parameters flow trend of lab measurements.

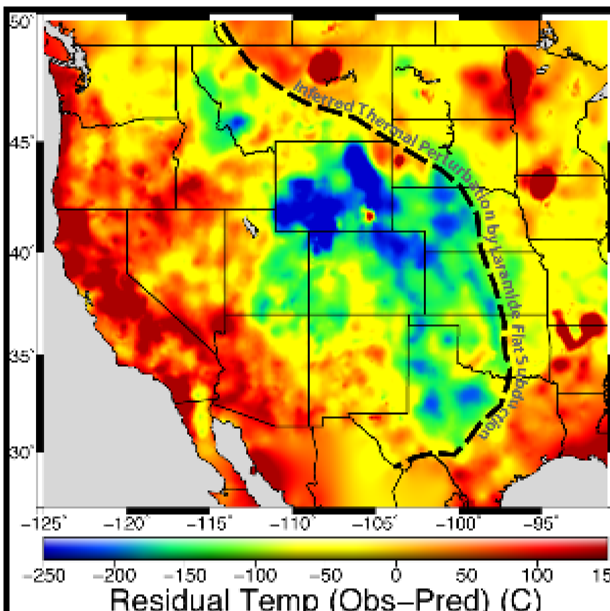

Figure 2: Residual difference in numerical model vs Observed values. Blue and green locales in mid-west and Rocky Mt indicate regions perturbed by flat-slab subduction.

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