Goldschmidt 2023 Abstract
https://doi.org/10.7185/gold2023.18642

Extensive Forearc Mantle Serpentinization Catalyzed by Early Subduction Zone Thermal Evolution

GABE S EPSTEIN[1], CAILEY B CONDIT[1], VICTOR E GUEVARA[2], ADAM F HOLT[3] AND RYAN STONER[3]

[1]University of Washington

[2]Amherst College

[3]University of Miami

Presenting Author: gepstein@uw.edu

Time-dependent (dynamic) subduction models demonstrate significant variation in slabtop and mantle wedge pressure-temperature conditions through the lifetime of a subduction zone. As subduction progresses the loci of key devolatilization reactions occur at higher pressures, extending from the upper plate moho (~1GPa) following initiation to subarc depths as subduction continues (~4GPa). Hydration of the forearc mantle wedge (via serpentinization) therefore likely occurs in large part during the early stages of subduction and progresses to greater depth as the subduction zone approaches thermal maturity (i.e. steady state). This process is not encompassed within kinematic/time-invariant models of subduction, leading to the inference that cold subduction zones have a relatively dry mantle wedge.

We couple the thermal structure predicted by a dynamically evolving subduction model [1] with the thermodynamic software Perple_X to quantify serpentinization capacity of the forearc mantle wedge. The model characterizes slab devolatilization and wedge serpentinization beginning directly after the onset of subduction through to quasi-steady state thermal conditions, spanning a time frame from 5 to 50 Myr after initiation. Our findings suggest that wedge serpentinization begins in the earliest and warmest phases of subduction. A comparison between our model and geophysical proxies for serpentinization reveals better agreement on a margin-to-margin basis than petrological results using time-invariant models. We calculate that forearc mantle wedges globally have sufficient fluid availability to maintain an average of ~40% serpentinization, with the coldest/youngest margins being ~10% serpentinized. This is in stark contrast to estimates derived from kinematic models suggesting an average of 13% serpentinization, with many margins containing <1% serpentine [2]. Our model suggests that strain localization and decoupling depth during subduction are inseparably linked to the stability and thickness of serpentine overlying the subduction interface. It likewise provides insights into the potential formation of serpentinite channels and their role in syn-subduction exhumation of high-P, low-T materials. Globally, the forearc mantle wedge environment may contain up to ~6-8x10^{21} g of H_2O, or ~0.5% of the modern ocean mass, making this region an important reservoir for deep earth volatile storage.

[1] Holt & Condit, 2021. G-cubed 22, e2020GC009476. [2] Abers et al., 2017. Nature Geoscience 10, 333-337.