Introduction

Observed axial morphology of Pāka Fā (VP) and Eastern Lau (3L) (southern and central regions along the Lau back-arc spreading center suggest that VP is more magmatically robust than EL. Despite EL spreading nearly twice as fast as VP. Geochemical and geophysical studies show a graduation decrease in subduction enhanced melting moving north from VP to EL. Also, geochronological studies detect a rapid decrease in subduction influence and melt production as the spreading center axis sweeps away from the Tofua Volcanic Arc. Furthermore, EL produces an anomalously thin crust for a robust spreading center. While 2-D numerical studies show a decrease in subduction influence and melting going from VP to EL, they have difficulty explaining the thinning of EL’s crust. To explain this observation, we run 3-D (Citcom) numerical experiments.

Consequences of 3-D flow on crustal production along the Lau back-arc spreading center

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1. 3-D Model, Anhydrous Melting (Above)

A. 2-D slice of the initial 3-D model at compatible plate boundaries today. The color bar refers to temperature in Celsius, the white vectors refer to flow velocity with the size of the vector indicating magnitude of flow, yellow contours represent the area of melt fraction with each contour representing 1% steps in melting. The white contour represents the area of weak nodes, which ranges from one order of viscosity reduction towards the edges of the contour and five orders of viscosity reduction in the center of the contour.

B. Above is the 3-D plot of 4% melt fraction of the initial 3-D model. Thick black lines represent Lau’s ridge axis and the Tofua Arc. Melting is anhydrous, shaded region represents a magnitude decrease in viscosity.

C. Three cross sections of mantle flow at depths 23.57, 49.05 and 73.90 km respectively. Blue vectors represent mantle flow velocity in the direction pointing. Larger arrows represent a higher velocity while small arrows represent a smaller velocity. Thick black lines represent the spreading ridge axis and Tofua Arc. Shaded region represents an order of magnitude viscosity reduction.

2. 3-D Model, Hydrous Melting (Below)

A. 2-D slice of the 3-D Model with Observed Kinematic/Plate Boundary Conditions and Viscosity reduction due to slab hydration. Modeling is at time = 5myr. The color bar refers to temperature in Celsius, the white vectors refer to flow velocity in cm/yr with the size of the vector indicating magnitude of flow, yellow contours represent the area of melt fraction with each contour representing 1% steps in melting. The white contour represents the area of weak nodes, which ranges from one order of viscosity reduction towards the edges of the contour and five orders of viscosity reduction in the center of the contour. Shaded region represents a viscosity decrease in viscosity.

B. A subduction model with no slab hydration generates a peak in relative melting area (unitless) and ridge-trench distance (km) from the trench (km) for the 3-D model with viscosity reduction due to slab hydration and hydrous melting. Circles represent numerically calculated areas of melting contours under and along the ridge axis. The vertical lines along the ridge distance from trench axis show different implementations of the hydrous/anhydrous melting barrier along the ridge axis.

C. Above is the relationship between relative melting area (unitless) and ridge distance from the trench (km) for the 3-D model with viscosity reduction due to slab hydration and hydrous melting. Circles represent numerically calculated areas of melting contours under and along the ridge axis. The vertical lines along the ridge distance from trench axis show different implementations of the hydrous/anhydrous melting barrier along the ridge axis.

Conclusions

1. A subduction model with no slab hydration generates a peak in relative melting close to EL where crust is known to be thinning.

2. A subduction model that includes viscosity changes in the mantle wedge due to slab hydration causes subdued relative melting increase with spreading rate and a ‘h Projectile’ shape in melting caused by the reversal of axial flow toward the southeast.

3. Finally, introducing hydrous melting in the mantle wedge increases the melt production under VP and causes a stepwise decrease in melt production at EL due to its decreased proximity to the slab-heterostatic region and its position above the saddle point in melt production; consistent with geophysical observations.

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