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Kinetics of metastable olivine constrained by seismic observations and dynamic models

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Abstract The transformation kinetics associated with the presence of a metastable olivine wedge in old and fast subducting slabs has been subject of many studies in the last years, mainly because the details are still not well constrained. In particular, there is no consensus on the blocking temperature which could inhibit the transformation from olivine to spinel. In the past, different authors have used different approaches to study this phenomena and its influence on the dynamics of a subduction zone.

Recently, based on anomalous later phases in the P wave coda and differential P-wave slowness, a wedge of metastable olivine was detected in the Marianas subduction zone. It is approximately 25 km width at 590 km depth and is truncated at 630 km.

In this work, we used a thermomechanical model to mimic the subduction in Marianas and try different blocking temperatures for the olivine/spinel transformation. Our model includes, among other features, realistic rheology, phase transformations, latent heat, a proper coupling between stress and thermal state of the slab and force balance of the system.

Our results show a positive correlation between the blocking temperature, depth of the wedge and its distance from the trench (or subduction angle). We compare them to the situation in Marianas and suggest that, according to our experiments, a blocking temperature for the olivine/spinel transformation of approximately 725°C would be the one that fits best.

The volume of the wedge presents some oscillations that seems to be related to a runaway effect of the transformation kinetics in the mantle transition zone. Namely, the interaction between latent heat and the advection of the isotherms due to the subduction velocity.

The inclusion of shear heating in the model was fundamental to be able to model such a subduction zone. Without shear heating, the slab shows a higher level of internal stress and the necessary bending to mimic the Marianas subduction zone cannot be reached.