Numerical Experimentation to Study the Role of Serpentinization and Deserpentinization In Bending and Unbending A Subducting Slab

*Jason Phipps Morgan[1], Albert de Monserrat[1]

1. Royal Holloway University of London

There is increasing consensus that the mantle of the downgoing oceanic plate at a subduction zone may be extensively serpentinized, and that the deserpentinization of the downgoing slab is related to both intermediate depth earthquakes (cf. Seno and Yamamaka, AGU Mon. 96, 1996; Peacock, Geology, 2001) and arc magmatism. Here we investigate the hypothesis that the serpentinization and deserpentinization of the downgoing slab may play a significant role in plate subduction itself, as a driving force for the bending and unbending of a subducting slab, in addition to its previously suggested role as a ‘lubricant’ along the plate interface and weak zones for enhanced normal faulting within the bending slab.

Mantle serpentinization involves an increase of >20% in volume from pure harzburgite to pure serpentinite. We assume that deep lithospheric faulting at the outer rise often provides pathways for seawater to hydrate the uppermost 30-50 km beneath the Moho, consistent with current seismic observations on the depths of outer rise seismicity, and estimates of the slab-temperature-dependent width of the double-Wadati-Benioff zone within subducting slabs. If serpentinization occurs to a significant degree, then it can provide both weak planes for shear slip (across deeply-penetrating faults) and a significant volume increase within the upper sections of the lithosphere mantle (around these faults). The volume increase from the serpentinization of the lithosphere would strongly promote plate bending in the region undergoing serpentinization. Likewise, deeper deserpentinization of the subducting slab and eclogitization of the subducting oceanic crust (suggested earlier by Steve Kirby) would act to unbend it deeper within the subduction zone.

We have developed a new 2-D compressible viscoelastoplastic code to study the mechanics of this process. The goal of our initial numerical experiments is to compare the deformation, stress patterns, and energetics of incompressible plate bending and unbending control experiments with experiments that include a waxing volume within the outer-rise plate-bending region, and a waning volume in the depth-interval of slab dehydration and eclogitization.

Serpentinization-linked slab-bending can significantly ease the mechanical work needed to subduct a plate, which would provide a possible resolution to the enduring paradox (Conrad and Hager, JGR, 1999) that the bending and unbending of the downgoing plate could consume even more energy than that available from the negative buoyancy of subducting lithosphere.

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