Exhumation of subducted mafic rocks in a dynamically evolving thermal structure: constraints from phase equilibria modelling

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The dominant mechanisms that control the exhumation of subducted rocks and how these mechanisms evolve through time in a subduction zone remain unclear. Dynamic models of subduction zones suggest that their thermal structures evolve from subduction initiation to maturity. The series of metamorphic reactions that occur within the slab, resultant density, and buoyancy with respect to the mantle wedge will co-evolve with the thermal structure. We combine dynamic models of subduction zone thermal structure with phase equilibria modeling to place constraints on the dominant controls on the depth limits of exhumation. This is done across the temporal evolution of a subduction zone for various endmember lithologic associations observed in exhumed high-pressure terranes: sedimentary and serpentinite mélanges, and oceanic tectonic slices.

Initial modeling suggests that both serpentinite and sedimentary mélanges remain positively buoyant with respect to the mantle wedge throughout all stages of subduction (up to 65 Myr), and for the spectrum of naturally constrained ratios of mafic blocks to serpentinite/sedimentary matrix. In these settings, exhumation depth limits and the “point of no return” (c. 2.3 GPa) are not directly limited by buoyancy, but potentially rheological changes in the slab at the blueschist-eclogite transition stemming from: the switch from amphibole-dominated to pyroxene-dominated rheology and/or dehydration embrittlement. These mechanisms may increase the possibility of brittle failure and hence promote detachment of the slab top into the subduction channel. For the range of temperatures recorded by exhumed serpentinite mélanges, the locus of dehydration for altered MORB at the slab top coincides with the point of no return (2.3 GPa) between 35 and 40 Myr, suggesting a strong temporal dependence on deep exhumation in the subduction channel.

Tectonic slices composed of 50\% mafic rocks and 50\% serpentinized slab mantle show a temporal dependence on the depth limits of positive buoyancy. For the range of temperatures recorded by exhumed tectonic slices, the upper pressure limit of positive buoyancy is ~2 GPa, and is only crossed between ~30 and 40 Myr after subduction initiation. Some exhumed tectonic slices record much higher pressures (2.5 GPa); thus, other mechanisms or lithologic combinations may also play a significant role in determining the exhumation limits of tectonic slices.

Future work includes constraining how the loci of dehydration vary through time for different
degrees of oceanic crust alteration, how exhumation limits and mechanisms may change with
different subducting plate ages, and calculating how initial exhumation velocities may vary
through time. Further comparison with the rock record will constrain the parameters that control
the timing and limits of exhumation in subduction zones.