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Exhumed mafic HP rocks are warmer than forearc oceanic crust in modern subduction zones suggesting preferential exhumation from young oceanic lithosphere

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Subduction of oceanic lithosphere cools the forearc mantle and the low temperature of the subducting oceanic crust below the forearc is a natural consequence of the advection of cold lithosphere. Almost all of the subducting crust is recycled to greater depth but in rare and punctuated episodes some blueschists and eclogites are exhumed. Their prograde P-T-t paths provide important insights into the conditions of the oceanic crust in which they subducted. We revisit the observation from various compilations of the maximum PT conditions seen in exhumed rocks indicates significantly warmer conditions below the forearc (200-300 K difference between 0.8 and 2.7 GPa) than predicted by thermal models. This could be due preferential exhumation of rock from young and warm oceanic lithosphere or exhumation during the warm early stages of subduction (Agard et al., ESR, 2009). Alternatively, the models might underestimate the subduction zone thermal structure by neglecting putative heat sources (Penniston-Dorland et al., EPSL, 2015).

By comparing models that include frictional and viscous shear heating as constrained by heat flow and other observations (Wada and Wang, G3, 2009) to those that ignore these heat sources (as in van Keken et al., JGR, 2011) we show that the average thermal effect of reasonable shear heating on the oceanic crust is only 50 K. We also show that the crustal PT conditions for young (<30 Ma) subducting lithosphere are quite similar to those inferred from the rock record.

We further test the hypothesis that certain heat sources may be missing in the models by constructing a global set of models that satisfy the rock record. This is achieved by arbitrarily —and in our view unphysically— increasing the heat production in the top of the subducting slab to 80 km depth. This would be equivalent to an increase of shear stress along the top of the slab of at least four times higher than is inferred from fault mechanics. While these models produce PT conditions in the subducting crust similar to those recovered from the rock record they fail to predict a large number of geophysical and geochemical observations: the heatflow predicted from the new models is at least twice the values observed over the forearc; the top of the oceanic crust is predicted to melt extensively below the forearc; the below-arc temperatures are on average 150 K in excess of those inferred from arc magmas; and the slab and overlying forearc mantle fully dehydrate at shallow levels in warm subduction zones conflicting with the presence of H_2O in arc magmas and the extensive serpentinization of the forearc mantle in those regions.

These combined tests show that the average exhumed rock record is systematically warmer than the average thermal structure of mature modern subduction zones. We infer that exhumation preferentially occurs after subduction of young and warm oceanic lithosphere. This conclusion is supported by dynamical arguments as the thermal buoyancy, rheological mobility, and fluid productivity are far greater in warm subduction zones than in cold ones.