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Compaction pressure goes global: Investigating fluid release and flow in subduction zones worldwide

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Subduction of oceanic slabs causes the influx of fluids through hydrated phases. Fluids are released by metamorphic dehydration reactions particularly when the slab comes in contact with the hot mantle wedge at depths greater than ~80 km. Fluid release can be diverse and occur at different depths inside the oceanic slab with sediments and uppermost oceanic crust generally dehydrating before the serpentinized mantle and gabbroic sections.

Significant progress has been made in recent years on geophysical imaging of subduction zones that highlight the thermal structure, the location of metamorphic dehydration reactions, and the presence of fluids in slab and mantle wedge (e.g., Kita et al., Tectonophysics, 2010; van Keken et al., Solid Earth, 2012; Shiina et al., GRL, 2013; Pommier and Evans, Geosphere, 2017, Abers et al., Nature Geoscience, 2017). In a complimentary fashion, geodynamical modeling provides first principles constraints on how fluids are released and transported.

Using a simplified modeling geometry, Wilson et al. (EPSL, 2014) showed the importance of compaction pressure gradients as an oft cited, but also frequently ignored, driving force for fluids in the slab. The inclusion of compaction pressure gradients causes the fluids to both be driven from their source to the arc and flow up in part parallel to the slab surface, explaining to at least some extent geophysical observations.

We have modeled the effects of compaction pressure gradients in a global set of subduction zone models (van Keken and Wilson, PEPS, 2023) and show that focusing of the fluids below the typical arc location (at where the slab is at about 100 km depth) is a common feature and that therefore the compaction pressure effects, along with the geometry of the cold corner in the mantle wedge, can naturally explain the position of the arc above subduction zones globally.