Supplementary Figure 1:
Pressure-temperature (P-T) paths for the top of the subducting basaltic basement rock, overlain on a phase diagram of metamorphic facies for mid-ocean ridge basalt (Hacker et al., 2003). Orange lines are model results for a transect through Cape Muroto on the Nankai margin (Spinelli and Wang, 2009); blue lines are model results for a transect through the northwestern portion of the Nicoya Peninsula on the Costa Rican margin (Rosas et al., 2016). Solid lines are from models with no hydrothermal circulation; dashed lines are from models with hydrothermal circulation. Darker shading indicates lower water content in oceanic crust. Facies abbreviations: pp – prehnite-pumpellyite; pa—prehnite-actinolite; eA -- epidote amphibolite; eb – epidote blueschist; jeb—jadite-epidote blueschist; lAE—lawsonite-amphibole eclogite; egA—epidote-garnet amphibolite; zAE—zoisite-amphibole eclogite; AE—amphibole eclogite. For the relatively hot Nankai margin, cooling of the system by hydrothermal circulation substantially affects the depth at which subducting crust experiences the dehydration associated with eclogitization (i.e. enters zAE facies). For the cooler Central American margin, hydrothermal circulation has a very small effect on the depth at which eclogitization and substantial dehydration of the subducting crust occurs.

Supplementary Figure 2:
Top panel: Observed and modeled surface heat flux for the transect through the Cascadia subduction zone near Mt. Rainier (as in Figure 6), here highlighting the sensitivity of modeled heat flux to permeability in the subducting aquifer. The gray line shows the modeled surface heat flux for a simulation without the effects of hydrothermal circulation (i.e. the reference simulation). The black lines show the modeled surface heat flux for simulations with the thermal effects of vigorous heat exchange in the subducting basement aquifer. For the bold black line, the pre-subduction aquifer permeability (k_0) is 10^{-9} m^2. Thin black lines show modeled heat flux for simulations with pre-subduction aquifer permeability of $10^{-9.33}$ m^2, $10^{-9.67}$ m^2, and 10^{-10} m^2.
Bottom panel: Modeled pressure-temperature (P-T) paths for subducting basaltic basement rock in the Cascadia transect (as in Figure 7), here highlighting the sensitivity of the P-T paths to permeability in the subducting aquifer.

Supplementary Table 1: Material compositions for petrological modeling

material	SiO_2	TiO_2	Al_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O at saturation	CO_2	reference
Sediment	57.9	0.8	15.4	6	3	2.4	2.9	2.4	9.2	0	Plank and Langmuir, 1998; van Keken et al., 2011
Mid-ocean ridge basalt	50.6	1.5	15.7	10.6	7.6	11.1	2.6	0.2	5.3	0	Pearce, 1976; Wilson, 1989; Hacker, 2008
Gabbro	50.6	0.9	16.1	6.2	9.2	12.5	2.8	0.1	5.2	0	Dick et al., 200; Hacker, 2008
Peridotite	47.9	0.2	2.7	7.7	37.1	4.3	0.3	0	10	0.1	Snow and Dick, 1995; Hacker, 2008

Supplementary Figure 3:
Modeled pressure-temperature (P-T) paths for subducting oceanic mantle in the Cascadia transect. Colors show the mineralogically-bound water content at saturation for peridotite. The solid line is for the top of the oceanic mantle (i.e. at the oceanic Moho). The dashed line is the modeled P-T

path for the top of the subducting slab (i.e. the P-T path serpentinite from the mantle wedge entrained into a mélange along the plate interface might experience). Circles show the P-T conditions on each of these paths at the position where the top of the slab is at 70 km depth.