

Slab Melting in Subduction Zones

SCHMIDT, Max^{1*} ; MANN, Ute¹

¹ETH Zurich, Switzerland

Depending on temperature, slab-to-mantle element transfer in the subarc region may either occur through fluids or melts. In this contribution we present pelite melting experiments systematically varying H₂O and CO₂ contents and review the presently available information on slab melting. Synthetic pelite model compositions containing variable proportions of H₂O (0.7-4.4 wt%) and CO₂ (0-4 wt%) was melted at 3-4.5 GPa and 750-1200 °C. The fluid-saturation concentration at 3-8 GPa (i.e. the H₂O stored in phengite as the only hydrous phase) is 0.8-0.9 wt% H₂O. We locate the fluid-absent solidus of the H₂O-pelite system at 3 to 4.5 GPa at 880 °C to 1050 °C about 150-200 °C higher than the wet solidus (3 to 4.5 GPa, 730 to 860 °C). CO₂ increases the fluid-saturated solidus temperature by ~30 °C but leaves the fluid-absent solidus temperature unchanged. For all systems considered, the onset of melting is controlled by phengite and only in the fluid-absent experiments K-feldspar becomes a product of melting (at 3 GPa).

Compiling all available information, we parameterize the amount of melt to be formed as a function of temperature for fluid-saturated and fluid-undersaturated conditions. Melt compositions themselves are meta- to peraluminous high Si-granites (71-77 wt% SiO₂ on a volatile free basis) with low Fe, Mg, and Ca contents and are uniform to ~50% melting when plotted as a function of melt fraction (but not temperature), almost independent of starting compositions. At >2 wt% bulk H₂O melts are sodic (K/Na=0.2-0.4), while at <1.5 wt% melts are mostly potassic (K/Na=0.9-1.7). Only the fluid-poor H₂O-CO₂ and the CO₂-only experiments of Thomsen and Schmidt (2008, EPSL) and Tsuno and Dasgupta (2011, CMP) produce significantly different melts i.e. rather potassic phonolites (Na being increasingly retained in jadeitic cpx with pressure). Near 5 GPa a fundamental change occurs: the H₂O-silicate solidus comes to an endpoint while in CO₂-rich systems a carbonatite replaces the silicate melt lowering the solidus temperature by more than 100 °C to 9 GPa.

Regarding the likelihood of sediment melting in the subarc region, only the wet solidus is within reach of the hottest geotherms of the thermal models that predict the highest slab-surface temperatures, i.e. none of the Arcay et al (2007, EPSL) slab surface P-T paths cross the solidus while for Syracuse et al. (2010, G3) about 7 out of 56 modeled slab segments have P-T-paths that may lead to significant melting for H₂O-saturated pelites at 3-4 GPa. As retention of significant amounts of fluids within a subducting lithology is not an option, flushing with fluids from dehydrating serpentinites would be the only option for achieving significant melting in the hottest subduction zones (at the required P-T conditions, there are no suitable reactions in the mafic crust or the sediments themselves). An alternative option to reach widespread pelite melting would be to dismiss the rigid slab surface concept and allow for sediment diapirs to rise into the hot mantle (Gerya and Yuen, 2003, EPSL; Behn et al, 2011, Nature Geosci.) in which case the pelites could bleed out their incompatible elements completely. Nevertheless, these diapirs are propelled by a density contrast resulting from partial melting and it remains unclear whether they could start rising without melting in the first place.

In conclusion, combining P-T paths, phase diagrams and degrees of melting suggests that significant pelite melting at a rigid slab-mantle interface appears to be a rather rare on present day Earth (and hence much more so for mafic materials), the only option for widespread pelite melting appears to be entrainment of the sediments into the mantle wedge. Removal of CO₂ through melting is utterly inefficient and as subsolidus metamorphic reactions lead to low X_{CO2} fluids, most of the subducted CO₂ will be fed into the deep beyond-arc C-cycle.

Keywords: slab melting, H₂O, CO₂, pelite