

Hydrous silicate melts and the deep mantle H₂O cycle

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H₂O exerts a powerful control on the location and composition of partial melts in Earth's deep interior by dramatically reducing the mantle solidus [1]. The minerals of the transition zone (410-670 km) can store ~3 ocean masses of H₂O derived from the dehydration of the serpentinized mantle portion of cool subducted slabs [2]. Upwelling across the upper boundary of the transition zone will lead to the release of water and the generation of hydrous silicate melts due to the relatively anhydrous nature of upper mantle minerals. If these melts are sufficiently dense, they will pond and be reabsorbed into the transition zone, efficiently stripping the upwelling mantle of its incompatible trace elements as described in the “transition zone water filter” model [3].

Here we report *ab initio* atomistic simulations of hydrous silicate melts under deep upper mantle to shallow lower mantle conditions and use them to parameterise density and viscosity across the ternary system MgO-SiO₂-H₂O (MSH). On the basis of phase relations in the MSH system, primary hydrous partial melts of the mantle have 40-50 mol% H₂O (Fig. 1). Our results show that these melts will be highly inviscid and positively buoyant at the upper and lower boundaries of the mantle transition zone except in very iron-rich compositions, where ≈ 75 % Mg is substituted by Fe (Fig. 2). This suggests that they will rapidly percolate upwards, reacting with and hydrating the upper mantle at the expense of the transition zone. As a result, large differences in H₂O concentration between the upper mantle, transition zone and lower mantle are difficult to maintain on timescales of mantle recycling. The MORB source mantle with ~0.02-0.04 wt% H₂O may be indicative of the H₂O content of the transition zone and lower mantle, resulting in a bulk mantle H₂O content of the order 0.5 to 1 ocean mass, which is consistent with geochemical constraints and estimates of subduction ingassing.

[1] Hirschmann (2006). *Annual Review of Earth and Planetary Sciences* 34, 629-653.

[2] Komabayashi & Omori (2006). *Physics of the Earth and Planetary Interiors* 156, 89-107.

[3] Bercovici & Karato (2003). *Nature* 425, 39-44.

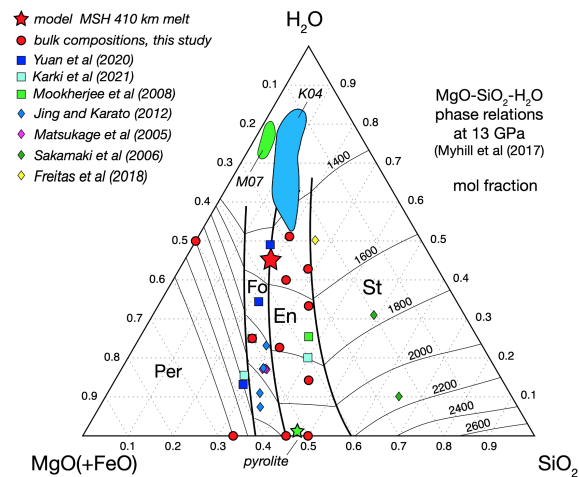


Fig. 1: Liquidus phase relations in the system MgO-SiO₂-H₂O (MSH) at 13GPa with phase boundaries after Myhill et al (2017) *GCA* 200, 408-421. Red circles show the compositions investigated in this study. The red star shows the composition of partial melt at 1550°C in equilibrium with model mantle peridotite (green star).

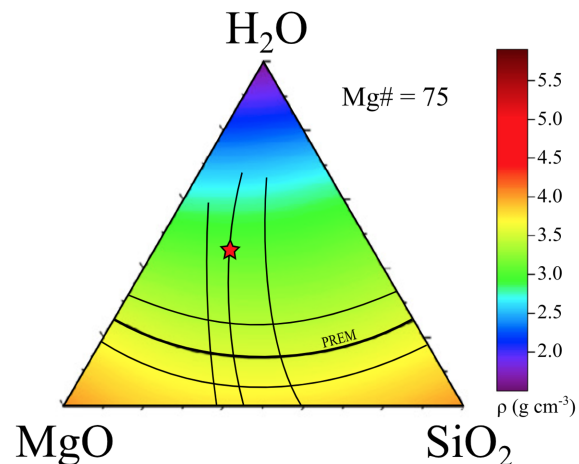


Fig. 2: Ternary contour plot showing density of a (Mg_{1-x}Fe_x)O-SiO₂-H₂O melt with x = .25 at 1800K and 13 GPa (the upper transition zone boundary). The black contour line delineates compositions with density equal to PREM, with a conservative estimate of 4% relative based on the range observed in previous experimental and theoretical studies.