

Composition and nature of melts, supercritical fluids and liquids formed by dehydration of subducted oceanic lithosphere

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At crustal pressures, phase relations in natural rock-H₂O systems involve low density aqueous fluids and/or high density hydrous melts. The wide miscibility gap between these two liquid phases leads to a dichotomy of mobile phases with quite distinct major element solubilities and trace element geochemical signatures. With increasing pressure, the fluid-melt miscibility gap closes until the crest of the miscibility gap intersects the fluid-saturated solidus, leaving a single supercritical liquid that has chemical and physical properties continuously evolving with temperature. The question is if the endpoint of the solidus is relevant for natural rock compositions. We have experimentally determined these endpoints in a variety of systems ranging from MOR basalt, to pelitic systems and to the simplified mantle systems MgO-SiO₂-H₂O (MSH) using different experimental techniques in the P-T range from 2.0 GPa/700 °C to 13.5 GPa/1300 °C. Supercriticality occurs over a wide range of P-T conditions ranging from 1 GPa/1100 °C for the SiO₂-H₂O system to 12-13 GPa in the SiO₂-poor part of the MSH system.

In the MORB system, major element compositions of the fluid/melt phase evolve from peralkaline, H₂O-rich, granite-like compositions to metaluminous, andesitic to basaltic compositions with increasing temperature. The endpoint of the fluid-saturated solidus occurs around 5 GPa and 1000 °C; thus, the dichotomy of fluid versus melt ceases to exist in the oceanic crust. Similar conditions were determined for pelitic to greywacke systems representing deep-sea sediments. In the mantle-like system MSH critical endpoints for fluid/melt solvi along the solidus are located between 12 and 13.5 GPa at 1100 °C. Melt compositions buffered by olivine and opx remain enstatite - olivine normative below the critical endpoint; in contrast, fluids below the endpoint become progressively enriched in MgO and are silica undersaturated (Mg/Si ratios >2) at pressures exceeding 6 GPa. Supercritical liquids coexisting with forsterite and enstatite or dense hydrous silicates are strongly silica undersaturated. The P-T evolution of fluids and liquids in the MSH system allows drawing conclusions regarding the effects of Mg-Si metasomatism in the overlying mantle wedge of a subduction system.

The consequences of the various nature of hydrous mobile phases emanating from hydrated subducted oceanic lithosphere were investigated in the MORB system by determining trace element partitioning between cpx, gar, amphibole, epidote, rutile, titanite, staurolite and phengite and liquid, the latter either being an aqueous fluid, a hydrous melt, or a supercritical liquid. Hydrous melts and supercritical liquids have almost identical trace element pattern. Thus, recycling rates of these elements are not indicative of melting, and in the fast and steep circum-pacific subduction zones, they most likely testify for production of a mobile phase from the subducting crust in the supercritical liquid regime (i.e. at pressure in excess of 4-5 GPa).

Modeling of trace element signatures of fluids, melts and supercritical liquids generated in or passing through eclogitic crustal lithologies during their ascent into the overlying mantle wedge indicate that (1) the mode of fluid advection - porous flow or - focused fluid flow - produces rather contrasting trace element signatures and (2) the presence or absence of accessory phases such as epidote, staurolite, rutile/titanite controls to a large extent the concentrations of high field strength, light REE elements and Th, U. Thus, inversion of geochemical compositions of igneous products in arc settings used to constrain the nature and composition of metasomatizing agents released from the subducted oceanic lithosphere is not straightforward and it is unlikely that an unequivocal solution is obtained.

Keywords: hydrous fluid, supercritical liquid, trace element partitioning, fluid metasomatism, high pressure experiments, subducted oceanic lithosphere