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Compositions and Nature of Melts, supercritical Fluids and Liquids liberated by Dehydration of subducted oceanic Lithosphere: Experimental Constraints and Consequences for Subduction Zone Metasomatism

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At crustal pressures, phase relations in natural rock-H_2O systems involve low density aqueous fluids (supercritical with respect to the endpoint of the H_2O liquid-vapor curve) 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. As pressure increases, the fluid-melt miscibility gap closes at ever lower temperatures, until the crest of the miscibility gap intersects the fluid-saturated solidus at its endpoint, leaving a single liquid that has chemical and physical properties continuously evolving with temperature, and which is supercritical with respect to the endpoint of the fluid-saturated solidus. The question is then, at what conditions would the endpoint of the solidus be relevant for natural rock compositions. We have experimentally determined these endpoints in a variety of systems ranging from K-free MOR basalt, to pelitic systems and to the simplified mantle systems MgO-SiO_2-H_2O (MSH) using different experimental techniques in the P-T range from 3.5 GPa/700˚C to 13.5 GPa, 1300˚C. Supercriticality occurs over a wide range of pressure – temperature conditions ranging from as low as 1 GPa/1100˚C for the SiO_2-H_2O system to 12-13 GPa in the SiO_2-poor to undersaturated part of the MSH system.

In the K-free MORB system, major element compositions of the fluid/melt phase evolve at all pressures from peralkaline, H_2O-rich, 'granitic' compositions to meta-luminous, 'andesitic' to basaltic compositions with increasing temperature. The end-point of the fluid-saturated solidus occurs between 5 and 6 GPa, and just above 1000

˚C indicating that at higher pressures, the dichotomy of fluid versus melt ceases to exist in the oceanic crust. Similar conditions were determined for pelitic and greywacke systems representing deep-sea sediments subducted together with basaltic oceanic lithologies (Schmidt et al., 2004, EPSL). In the mantle-like system MSH measured and extrapolated (from Stalder et al., 2001, CMP,) critical endpoints for the fluid/melt solvus along the inferred mantle solidus are located between 12 and 13.5 GPa around 1100˚C. Whereas melt compositions buffered by olivine and opx remain enstatite – olivine normative below the critical endpoint, fluids below the endpoint become progressively enriched in MgO and are enstatite undersaturated (Mg/Si ratios $>$ 2) at pressures exceeding about 6 GPa. At all pressures and for all bulk compositions investigated the MgO/SiO_2 ratio increases with increasing temperature. Supercritical liquids (above the critical endpoints) coexisting with forsterite and enstatite or an alphabetic dense hydrous silicate (clinohumite, chondrodite or phase A) are strongly silica undersaturated. The P-T evolution of fluids and liquids in the MSH system allows drawing some first order conclusions regarding the effects of Mg-Si metasomatism in the overlying mantle wedge of a subduction system leading to regions with silica enrichment or depletion.

The consequences of the solidus' endpoint on the trace element characteristics of the metasomatizing agents emanating from the subducted oceanic crust produced by the breakdown of hydrous phases or by fluxing with H_2O-rich fluids originating from dehydration of the underlying serpentinites were investigated in the K-free MORB system by measuring trace element partitioning between cpx, gar and liquid, the latter either being an aqueous fluid, a hydrous melt, or a supercritical liquid. Hydrous melts and supercritical liquids (the latter down to at least 200 ˚C below the hypothetical extension of the solidus) are almost indistinguishable in their trace element pattern, the mobility of Th and Be is even increased in the supercritical liquid (Kessel et al, 2005, Nature). 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 (beyond the endpoint of the solidus), i.e. at pressure in excess of 5 GPa corresponding to depth of 160km.