# Fluids, melts, and supercriticality in the MSH system and element transport in subduction zones

M.W. SCHMIDT AND E. MELEKHOVA

Dep.Earth Sciences, ETH Zürich, Switzerland (max.schmidt@erdw.ethz.ch, elena.melekhova@erdw.ethz.ch)

The dichotomy of aqueous fluids and hydrous melts which includes fluid saturated melting is known to be limited in pressure, as the critical temperature of the miscibility gap between the two liquid phases strongly decreases with pressure. The critical P-T curve of the immiscibility gap intersects with the fluid saturated solidus at a critical pressure between 1 ($SiO_2$-$H_2O$) and 12 GPa (MgO-$SiO_2$-$H_2O$), nevertheless, the critical pressures for natural rock systems are largely unknown and under discussion. This discussion stems from the imperfection of all available experimental methods, which will be critically reviewed.

Our new experimental results on the MSH peridotite model system suggest that the entire system goes supercritical around 12 GPa, where phase A and chondrodite are stable at the solidus in the Mg-rich portion of MSH. Supercriticality moves stepwise from the $SiO_2$-rich side to the MgO-rich side, and hitherto insufficiently defined equilibria involving enstatite are needed to define the MSH phase diagram completely. While supercriticality eliminates fluid saturated melting, it is irrelevant to fluid-absent melting, and thus to devolatilization of deeply subducted oceanic mantle. Even above 12 GPa, phase E has a realistic chance to undergo fluid absent melting in thermally relaxing subducted lithosphere.

Secondly, while the question of supercriticality of the fluid-melt pair is petrologically challenging, it is, also in the presence of a fluid, of moderate practical relevance to the real world. In subduction scenarios, we do expect to have one liquid (either fluid, or melt or supercritical liquid), compositionally buffered by and coexisting with the residual minerals. The main questions relate then to solubilities of key elements in and to the viscosity and wetting behavior of this liquid.

# Is “ballen quartz” diagnostic for shock metamorphism?

M. SCHMIEDER AND E. BUCHNER

Institut für Geologie und Paläontologie, Universität Stuttgart, Herdweg 51, D-70174 Stuttgart, Germany

Ballen quartz has been observed in impactites from a number of terrestrial impact structures, predominantly in impact melt rocks, suevites, and target rock clasts affected by strong post-shock heating. In thin section, ballen are generally roundish to oval-shaped and typically range in size from several microns to ~200 µm. Ballen rims may vary in brightness and colour, and appear as curved open fractures, fractures filled by submicroscopic phases, or very faint lines. Accordingly, ballen quartz, with its typical crackled “fish-scale” pattern, has turned out to be a distinctive textural feature suggestive for shock metamorphism [1-5].

In addition to the reports available in literature, we detected ballen quartz in impact melt rocks from Manicouagan, Rochechouart, Kara, Terny, and strongly heated crystalline basement clasts from the Ries crater and Ilyinets. As ballen quartz is known from very small but also the largest terrestrial impact structures (e.g., Tenoumer or Chicxulub), one must assume that ballen quartz should have been primarily present at all terrestrial impact sites.

Three types of ballen quartz (homogenous ballen, optically individual ballen, and microcrystalline ballen) are distinguished by their optical properties corresponding to different shock stages [2]. Various models of ballen quartz formation have been proposed to date, such as by prograde silica transformations in the solid state [3;4] or by the melting of silica, lechatelierite formation, and retrograde recrystallisation [1;5]. However, it is widely accepted that quartz ballen represent pseudomorphs after cristobalite [3-5]. The formation mechanism of ballen quartz, nevertheless, still appears to be somewhat enigmatic.

Domains of typical “granular cristobalite” in siliceous volcanic rocks [6], fulgurites [7], and heated industrial quartz ceramics [8] - i.e., non-impact materials of emphasised thermal history - display essentially the same textural pattern, which further suggests that ballen quartz originates from granular cristobalite and that ballen texture develops during cristobalitization of silica (and the high-low inversion of cristobalite [5]) at high temperatures. Therefore, ballen quartz might not be restricted to impactites, and we put into question that the sole presence of ballen quartz can be considered as reliable evidence for shock metamorphism.

**References**

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