Water-saturated solidus and second critical endpoint of peridotite determined by textures and chemistry of the quenched liquid

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Water-saturated ('wet') solidus of mantle peridotite defines the initial melting temperature of Earth's mantle under water-saturated conditions and the second critical endpoint (SCEP) marks the end of the wet solidus. However, the location of the wet solidus remains an outstanding issue for over 50 years and the position of the SCEP is hotly debated. Published wet solidus shows a difference of 200–600°C at given pressures, meanwhile, reported SCEP ranges from < 4 to > 6 GPa. Using a large-volume multi-anvil apparatus SAKURA-2500 at Guangzhou Institute of Geochemistry, we investigated the water-saturated melting behavior of a fertile peridotite (at 3–6 GPa, 950–1200 °C) and obtained well-preserved quenched liquid. Based on the texture and chemistry of the quenched liquid, we successfully determined the wet solidus and the SCEP of peridotite (Fig A, bold red curve). Experiments were carried out with 25mm edge MgO octahedron (25M) with $LaCrO_3$ heater of 9mm OD and 6mm ID. Staring material was a mixture of glass and $Mg(OH)_2$ with the bulk chemical composition equivalent to a fertile peridotite KLB-1 + 10 wt% H_2O.

At 3 GPa, the quenched fluids exhibit fragile fibres at 950 ℃ and spherule–fibre mixtures at > 1000 ℃ (Fig. B&C). While the quenched hydrous melt appears as a felt-like mass or as dendritic crystallites and coexists with the fluids (Fig. C). We interpreted the presence of spherule–fibre mixtures as evidence for aqueous fluid above the solidus and fragile fibres as evidence for aqueous fluid below the solidus. Thus, the occurrence of quenched melt and spherule–fibre mixtures indicate that the wet solidus lies between 950 and 1000 ℃ at 3 GPa and that 3 GPa is lower than the critical pressure. The most important textural difference between the run products at 3 GPa and those at other pressures (4 and 6 GPa) is the presence of aqueous fluids in the former (Fig. B&C) and the absence of which in the latter (Fig. D&E). The spherule–fibre mixtures were not found in the 4 and 6 GPa run products. Liquids quenched from 4 and 6 GPa run products are homogeneous (SCF supercritical fluid), suggesting that Pc is lower than 4 GPa.

Compositions of the liquids were analyzed by averaging broad area using EDS. We find that the liquid compositions become more deficient in silica and richer in olivine components with increasing pressures. In conjunction with previous studies, the compositions of silicate melts or SCFs change regularly with pressure: andesitic at 1 GPa, boninite-like at 3 GPa, picritic at 4 GPa, and kimberlite-like at pressures > 5 GPa. These results propose that ultra-basic magmas can be formed in subduction zones at low temperatures, high pressure, and H_2O rich conditions. On the basis of present experiments and detailed observation on the cross section of north Japan based on seismology and petrology, we propose a new magma genesis model in subduction zone (Takahashi & Wang, JpGU2020, S-CG64).

Reference:

The water-saturated solidus and second critical endpoint of peridotite: Implications for magma genesis within the mantle wedge, Jintuan Wang, Eiichi Takahashi, Xiaolin Xiong, Linli Chen, Li Li, Toshihiro Suzuki and Michael Walter (2020) J. Geophys. Res.: Solid Earth, Vol.125, in press.

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