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Experimental investigation of the genesis of volatile-bearing melts at the bottom of the Earth's upper mantle

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Melting processes have differentiated Earth through its history, leading to the formation of the crust, mantle and core, and influenced the composition of the atmosphere through the release of volatiles at the surface. Large-degree melting at mid ocean ridges or subduction zones occurs within ~150 km depth in the mantle, induced by plate tectonics. However, low-degree partial melting occurs at much greater depths in the mantle due to the presence of volatiles (COH) lowering the solidus of silicate rocks. These low-degree melts are enriched in incompatible elements (including volatiles) and as such, understanding their formation is key for understanding the geochemical evolution of our planet.

At the boundary between the upper mantle and the transition zone, at ~410 km depth, seismological studies have long indicated the presence of a hydrous melt layer. The formation of this melt is triggered by the release of H_2O when the hydrous mantle upwells from the transition zone into the upper mantle where minerals have a lower H_2O storage capacity. While mineral physics and geochemical models support the formation of this melt layer, experimental constrains based on the distribution of H_2O between minerals and melts do not favor melting at 410 km compared to other depths in the upper mantle. However, these experimental constrains have been determined in H_2O-bearing systems. Experiments including CO_2, the second most abundant volatile in the mantle, are more representative and might provide new insights into this controversy.

We performed high-pressure high-temperature multianvil experiments at 13 GPa and 1300-1900 °C to better understand the distribution of H_2O between minerals and melts in a COH-bearing system at 410 km depth. Nanoscale secondary ion mass spectrometry and elastic recoil detection analyses were conducted to determine the volatile content of the minerals, while phase relations were used to constrain the melt composition. We discuss the distribution of H_2O determined in COH-bearing systems and evaluate the role of volatiles in the formation of melts at the bottom of the upper mantle.