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Partial melting of hydrated carbonaceous chondrites: Redox evolution and links to oxidized achondrites

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Understanding the early differentiation of hydrous, oxidized planetesimals is essential for reconstructing the chemical and thermal evolution of the outer Solar System. CM carbonaceous chondrites record some of the highest oxygen fugacity among chondritic groups [1] and contain up to ~9 wt% H_2O in hydrated phases [2], making them ideal analogues for incipient melting in oxidized volatile-rich planetary embryos. However, the extent to which melting and devolatilization modify CM-like materials, and whether these processes can produce the redox conditions of oxidized achondrites (angrites and brachinites) [3,4], remains unclear.

We performed partial melting experiments on fragments of the CM2 chondrite MCY 12002 at 1 GPa and 1050-1400°C for 1-24 h. Near the solidus (1050-1100°C), heating triggers breakdown of hydrated matrix phases and metamorphic recrystallization, producing fine-grained olivine-dominated assemblages. Small melt fractions (<5 area%) appear at 1050-1150 °C, increasing to ~16 area% at 1400 °C. Residues comprise olivine with minor Al-rich low-Ca pyroxene, rare kirschsteinite, and spinel. A S-rich phase persists at all temperatures.

Silicate melt compositions evolve nonlinearly, from basanite at 1050°C to basalt at 1150 °C, basaltic-andesite at 1200–1300°C, and returning to basalt at 1400°C. Devolatilization of C-O-H species (H_2O, CO_2) drives redox evolution. Without external buffering, experiments reproduce the oxygen fugacity of oxidized achondrites (angrites and brachinites) from a more oxidized CM precursor.

Progressive volatile loss during early melting can lower oxygen fugacity by ≥6 log units, bridging the redox gap between carbonaceous chondrites and oxidized achondrites without requiring a missing reservoir of highly oxidized bodies. Temperature and devolatilization primarily control melt composition, sulfide behavior, and redox evolution in CM-like planetesimals. These results refine our understanding of oxidized parent body evolution and have implications for the NASA Psyche mission, as metal-rich M-type asteroids may represent cores of oxidized, sulfur-bearing planetesimals [5].

References: [1] Schrader D. et al. (2021) GCA 295, 185–207. [2] Suttle M. et al. (2021) GCA 293, 239–256. [3] Jurewicz A. J. G. et al. (1993) GCA 57, 2123–2139. [4] Gardner-Vandy K. et al. (2013) MAPS 48, 2006–2025. [5] Crossley S. et al. (2020) GCA 280, 264–288.

