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Efficient water loss during thermal processing of planetary building blocks

MEGAN EVE NEWCOMBE[1], LIAM D. PETERSON[2], SUMEDHA DESIKAMANI[1], CONEL M. O'D. ALEXANDER[3], SUNE GRØNLUND NIELSEN[2], JIANHUA WANG[3], RICHARD D ASH[1], PHILIP M. PICCOLI[1] AND EMMA BULLOCK[3]

[1]University of Maryland

[2]Woods Hole Oceanographic Institution

[3]Carnegie Institution for Science

Presenting Author: newcombe@umd.edu

Thermal processing is thought to exert an important control on the water budgets of planetary building blocks. Heat produced by decay of short-lived radionuclides drove thermal metamorphism, melting, and formation of magma oceans in planetesimals that accreted within the first few million years of Solar System formation. To examine the efficiency and timing of water loss during thermal processing, we have analyzed water concentrations of nominally anhydrous minerals (NAMs) and quenched melts in meteorites that represent various stages of thermal processing, from moderate thermal metamorphism (as represented by type 4 – 6 ordinary chondrites; [1]), to incipient melting (as represented by primitive achondrites; [2, 3]), to the magma ocean stage (as represented by achondrites; [4, 5]).

Ungrouped achondrites from the inner and outer Solar System have NAM water abundances that are close to our blank levels (<2 µg/g H_2O; [4]). We can test whether water loss occurred before the magma ocean stage by examining the volatile contents of primitive achondrites [2, 3]. Our measurements of water in NAMs from acapulcoite and lodranite primitive achondrites suggest that the acapulcoite-lodranite parent body contained <38 µg/g H_2O [3], indicating that water loss from this parent body occurred prior to incipient melting.

To constrain water loss during thermal metamorphism, we analyzed water in NAMs and mesostases in type 4 – 6 ordinary chondrites (OCs) [1]. There is clear evidence that the OCs accreted water-ice [6]. The majority of our analyses fall near the detection limits (~1 – 12 µg/g H_2O), suggesting that water loss from moderately metamorphosed OC NAMs is efficient, or that OC NAMs do not form with or acquire significant water via implantation or alteration [7, 8]. Our results support a model of water delivery to Earth via minimally thermally processed materials.

[1] Desikamani et al. 2024 *LPSC abstract #2679*; [2] Peterson et al. 2023 *GCA*; [3] Peterson et al. 2024 *GCA*; [4] Newcombe et al. 2023 *Nature*; [5] Peterson et al. 2023 *EPSL;* [6] Alexander et al. 1989; *GCA*; [7] Jin and Bose (2021) *Astrophys. J.* [8] Harries et al. (2023) *MaPS*