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TEMPERATURES OF AQUEOUS ALTERATION ON CARBONACEOUS CHONDRITE PARENT BODIES

W. Guo[1], M. Perronnet[2], M. E. Zolensky[2], and J. M. Eiler[1]. [1]Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125, USA. E-mail: wfguo@gps.caltech.edu. [2]NASA Johnson Space Center, Houston, TX 77058, USA.

Introduction: Aqueous alteration of primitive meteorites is among the earliest and the most widespread geological processes in the solar system [1]. A better understanding of these processes would help us constrain the early evolution condition of the solar system and test models of thermal and chemical evolution of planetesimals. In this study, we extended our previous work on CM chondrites [2, 3] by further applying carbonate clumped isotope thermometry [4, 5] to other types of carbonaceous chondrites (GRO 95577, CR1; Orgueil, CI; and Tagish Lake, ungrouped type 2) to determine the conditions of their aqueous alteration. Carbonate in GRO 95577 is almost exclusively calcite; both Orgueil and Tagish Lake contain complex mixtures of several carbonates, which necessitated stepped phosphoric acid digestion to separately analyze calcite, dolomite/ankerite and breunnerite. CO_2 gases derived from these acid digestions are exceptionally rich in sulfur and organic contaminants. While so far no consistent evidence suggests their influences on Δ_{47} after extensive purification, we are continuing working on this issue.

Results and Discussion: $\delta^{13}C_{PDB}$ and $\delta^{18}O_{VSMOW}$ values of carbonates we observe are consistent with previous studies [6–8]. Temperatures of carbonate formation (±10 °C, 1σ) are: 6–40 °C for calcite in GRO 95577; 26 °C for dolomite and −6 °C for breunnerite in Orgueil; 50 °C for calcite, 34 °C for dolomite and −26 °C for breunnerite in Tagish Lake. These estimated alteration temperatures are within or below those estimated for CM chondrites (20–71 °C) [2, 3], and thus preclude alteration temperature variations as the principle cause of differences in the degrees of alteration between the CM versus CI and Tagish Lake. Given previous evidences for the sequence of carbonate formation in carbonaceous chondrites (calcite before dolomite before breunnerite) [9, 10], our results suggest carbonate formation (and aqueous alteration) occurred while the parent bodies were cooling.

Based on the known temperature-dependent carbonate-water oxygen isotope fractionations, we estimated $\delta^{18}O_{VSMOW}$ of the water from which these carbonates grew (±2‰, 1σ): −12.3‰ to −7.1‰ for calcite in GRO 95577; −2.1‰ for dolomite and −25.2‰ for breunnerite in Orgueil; 10.3‰ for calcite, 5.1‰ for dolomite, and −15.9‰ for breunnerite in Tagish Lake. These large variations in $\delta^{18}O$ of formation water were accompanied by relatively small variations in $\Delta^{17}O$ [8] (e.g., ~23‰ variation in $\delta^{18}O$ versus <0.2‰ variation in $\Delta^{17}O$ in Orgueil); this result contrasts with previous models of aqueous alteration of the carbonaceous chondrites [11, 12], suggesting that our understanding of the hydrology of their parent bodies must be revised.

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AGES OF LARGE SiC GRAINS FROM MURCHISON

F. Gyngard[1], S. Amari[1], E. Zinner[1], and R. S. Lewis[2]. [1]Laboratory for Space Sciences and Department of Physics, Washington University, St. Louis, MO 63130, USA. E-mail: fmgyngar@wustl.edu. [2]Enrico Fermi Institute and Chicago Center for Cosmochemistry, University of Chicago, Chicago, IL 60637, USA.

Introduction: Estimating the presolar residence time of SiC grains in the interstellar medium (ISM) has been a long-standing problem. Previous studies, on bulk samples, have focused on cosmogenic production of ^{21}Ne [1, 2] and ^{126}Xe [3] in estimating cosmic-ray exposure ages. Ott et al. [3] found no clear evidence for cosmogenic ^{126}Xe, implying very short cosmic-ray exposure histories, while ages inferred from ^{21}Ne production have largely been invalidated because of spallation recoil loss [4]. We measured Li isotopes in large presolar grains and found ^{6}Li enrichments of up to ~300‰ [5]. Assuming that these excesses are from cosmic-ray spallation in the ISM, we can infer lower limits on the length of time individual presolar SiC grains spent in the ISM.

Experimental: Grains from Murchison separates LS and LU [6] were placed on a clean gold foil with a micromanipulator and pressed with a quartz disk. SEM-EDX analysis identified forty grains as SiC, ranging in size from 5 to 60 µm. With the Washington University NanoSIMS, Li, B, C, Si, and S isotopic ratios were determined on nine of the largest grains.

Results: Eight out of 9 grains show ^{6}Li enrichments, likely due to spallation from C by cosmic rays. Using Li production rates calculated for grains with radii less than 1 cm by Reedy [7], we infer cosmic-ray exposure ages of the eight grains with ^{6}Li excesses from 24 to 1.2 Gy. Two grains have irradiation ages less than 40 My, four grains are between 100 and 500 My, and two grains have ages greater than 500 My. The dominant source of error in these age determinations is uncertainty in the production rate, as it depends critically on the cross sections of the responsible spallation reactions for realistic targets, and in the interstellar flux of galactic cosmic rays, both poorly constrained quantities. Resulting errors are ~30–40%. These age determinations do not account for any spallation recoil loss or self-shielding; however, these effects would only increase the ages reported here.

Long interstellar exposure ages are not necessarily inconsistent with previous results indicating young SiC exposure ages [3], as the large L-series SiC measured here are morphologically and isotopically distinct from other presolar SiC [5]. Jones et al. [8] estimated SiC grain lifetimes in the ISM to range up to 1.5 Gy, consistent with the ages we have calculated. These results may suggest that some large LS+LU SiC grains come from stars that ejected grains into the ISM before the parent stars of most smaller SiC grains found in meteorites. The large size of these LS+LU grains likely allows them to better survive destruction by SN shock waves and nebular processing in the ISM.

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