EARLY FLUID ACTIVITY ON THE RYUGU PARENT ASTEROID INFERRED FROM ^{53}MN-^{53}CR AGES OF RYUGU CARBONATE.

K. A. McCain[1], N. Matsuda[1], M.-C. Liu[1], K. D. McKeegan[1], A. Yamaguchi[2], M. Kimura[2], N. Tomioka[3], M. Ito[3], N. Imae[2], M. Uesugi[4], N. Shirai[5,6], T. Ohigashi[7,8], R. C. Greenwood[9], K. Uesugi[4], A. Nakato[10], K. Yogata[10], H. Yuzawa[7], Y. Kodama[11,†], K. Hirahara[12], I. Sakurai[13], I. Okada[13], Y. Karouji[10], S. Nakazawa[10], T. Okada[10], T. Saiki[10], S. Tanaka[10], F. Terui[14], M. Yoshikawa[10], A. Miyazaki[10], M. Nishimura[10], T. Yada[10], M. Abe[10], T. Usui[10], S. Watanabe[15], and Y. Tsuda[10,16]. [1]Dept. of Earth, Planetary, and Space Sciences, University of California, Los Angeles, CA 90095, USA (kamccain@ucla.edu, nozomi32@ucla.edu) [1]UCLA, [2]NIPR, [3]JAMSTEC Kochi, [4]JASRI/SPring-8, [5]Tokyo Met. Univ., [6]Kanagawa Univ., [7]UVSOR/IMS, [8]PF/KEK, [9]Open Univ., [10]JAXA/ISAS, [11]Marine Works Japan, Ltd., [12]Osaka Univ., [13]Nagoya Univ., [14]Kanagawa Inst. of Tech., [15]GSES/Nagoya Univ., [16]SOKENDAI, [†]Now at Toyo Corp.

Introduction: The Hayabusa2 mission returned approximately 5.4 g of highly aqueously-altered material resembling the CI (Ivuna-type) chondrites from the C-type asteroid Ryugu [1,2]. In order to understand the timing and duration of aqueous alteration which occurred on the Ryugu parent body, we measured the ^{53}Mn-^{53}Cr ($t_{1/2}$ = 3.7 Myr) ages of carbonates in two Ryugu particles, A0037 and C0009. We then use these carbonate formation ages to constrain the accretion time and size of Ryugu's parent body.

Methods: The $^{55}Mn^+/^{52}Cr^+$ and $^{53}Cr^+/^{52}Cr^+$ ratios of Ca-carbonate, dolomite, and breunnerite from particles A0037 and C0009 were measured using the CAMECA ims-1290 ion microprobe at UCLA. Analyses were performed using a 1 nA $^{16}O_3^-$ beam generated by an Oregon Physics Hyperion-II plasma ion source [3]. An MRP of ~5500 was used to separate $^{52}Cr^+$ from $^{28}Si^{24}Mg^+$ and $^{53}Cr^+$ from $^{52}CrH^+$. Analysis spots were presputtered using an 8 × 8 or a 4 × 4 µm raster to remove surface Cr contamination before reducing the raster to 5 × 5 or 2 × 2 µm for analysis. The effective spot size was approximately 8 × 10 µm^2.

The instrumental mass fractionation for the Cr isotopic ratio was corrected by comparison to repeated measurements of a terrestrial dolomite with trace amounts of Cr. The relative sensitivity factor (RSF) between Mn and Cr is defined as $RSF = (^{55}Mn / ^{52}Cr)_{True} / (^{55}Mn / ^{52}Cr)_{SIMS}$ and was determined using a combination of San Carlos Olivine and ion-implanted calcite, dolomite, and breunnerite standards.

Results: The inferred initial $^{53}Mn/^{55}Mn$ ratios for Ryugu carbonates are $6.8 \pm 0.5 \times 10^{-6}$ (MSWD = 0.7) for A0037 dolomite and $6.1 \pm 0.9 \times 10^{-6}$ (MSWD = 0.3) for C0009 dolomite, Ca-carbonate, and breunnerite (all errors 2SE). When these ratios are calibrated relative to the initial $^{53}Mn/^{55}Mn$ of the D'Orbigny angrite [4], an 'anchor' sample with a well-defined Pb-Pb crystallization age [5,6], we calculate that A0037 and C0009 carbonates formed at 4566.9 ± 0.4 Ma and 4566.3 ± 0.4 Ma, respectively—that is, within the first 1.4 Myr after the CAI 'time zero' age of 4567.3 Ma [7]. This is significantly older than inferred from previous studies of CI chondrites [8,9].

Discussion: These old carbonate formation ages stand in contrast to ages obtained from carbonate in CI chondrites, most of which were thought to have formed 4−6 Myr after CAI formation [8,9]. We attribute this difference to our use of matrix-matched standards for the dolomite and breunnerite analyses. Had we corrected measured Mn^+/Cr^+ using a relative sensitivity factor derived only from analyses of calcite, we would have obtained ages of 3.0 Myr and 3.5 Myr after CAI formation for A0037 and C0009 carbonate respectively.

Size and timing of accretion of the Ryugu parent body. Formation of carbonate within the first 1.4 Myr after CAI suggests a significantly different formation scenario than the large (>50 km) parent bodies accreting ~3–3.5 Myr after CAI which had been previously inferred for the parent bodies of CI chondrites [8,9]. Early accreted parent bodies would have had a high abundance of ^{26}Al to drive water loss or even silicate melting and chemical differentiation if they cannot effectively conduct heat away by radiation. By modeling parent bodies accreting as mixtures of 50% chondritic material and 50% water ice, we find that parent bodies accreting before 1.4 Myr must be smaller than ~17 km in diameter for the internal temperature to remain below 400 K and avoid water loss. Alternatively, Ryugu material could have been formed in a larger progenitor body which was disrupted by impact before reaching peak temperatures. This multi-stage scenario is supported by petrographic and shock characteristics observed in Ryugu particles [10,11].

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