CARBONACEOUS PRESOLAR GRAINS IN ASTEROID RYUGU. L. R. Nittler[1,] J. Barosch[1], B. T. De Gregorio[2], R. M. Stroud[2], H. Yabuta[3], H. Yurimoto[4], T. Nakamura[5], T. Noguchi[6], R. Okazaki[7], H. Naraoka[7], K. Sakamoto[8], S. Tachibana[8,9], S. Watanabe[10], Y. Tsuda[8] and the Hayabusa2 Organic Macromolecule Initial Analysis Team, [1]Carnegie Institution for Science (Washington, DC, USA) (lnittler@ciw.edu), [2]U.S. Naval Research Laboratory (Washington, DC, USA), [3]Hiroshima University (Japan), [4]Hokkaido University (Japan),[5]Tohoku University (Japan), [6]Kyoto University (Japan), [7]Kyushu University (Japan), [8]JAXA, [9]Univ. of Tokyo (Japan), [10]Nagoya University (Japan).

Introduction: JAXA's Hayabusa2 spacecraft returned over 5 g of material from two touchdown sites on C-type asteroid Ryugu to Earth in December 2020. One of the science goals of the mission is to characterize and ascertain the inventory of preserved presolar grains in Ryugu [1]. Presolar grains are tiny and rare dust grains that formed in prior generations of stars and were part of the original building blocks of the Solar System. Identified by their extremely unusual isotopic compositions they provide a wealth of information about galactic, stellar, interstellar, and asteroidal evolutionary processes [2]. We report the identification of ten presolar C-rich grains, mostly or entirely SiC, identified in Ryugu particles from both touchdown sites, fortuitously found while characterizing the micro-scale isotopic composition of organic matter in the samples [3]. Isotopic compositions are in the range of presolar SiC grains found in meteorites and the abundance is in good agreement with that seen for CI and other primitive chondrites.

Methods: As part of the Hayabusa2 Organic Macromolecule Initial Analysis Team [3], we used the Cameca NanoSIMS 50L ion microprobe at the Carnegie Institution of Washington to map H, C, and N isotopes at the 100-200 nm scale of Ryugu samples; see [4] for details. We have analyzed both microtomed slices deposited on Si wafers and whole particles pressed into Au foils, including grains from both Chambers A and C of the Hayabusa2 sample return container. Highly ^{13}C-rich (i.e., $\delta^{13}C>250$‰, the maximum anomaly seen in meteoritic organics) presolar grains were clearly visible in some NanoSIMS images (e.g., Fig. 1); these were re-measured for C, N, and Si isotopes with higher pixel resolution than used for the initial mapping in order to resolve them as much as possible from surrounding materials. However, due to the ubiquity of organic matter in the samples, complete separation of C and N signals arising from organics from those intrinsic to the presolar grains was not always possible.

Results: The NanoSIMS C-isotope images revealed a total of ten ^{13}C-rich grains ranging in size from ~100 – 250-nm. Three were found in microtomed sections and seven in pressed Ryugu particles. Nine of them show clear correlation with ^{28}Si signals and are hence inferred to be SiC, the best-studied presolar phase. One grain in a microtome section did not show such a correlation, so it may be graphite. However, its small size coupled with the Si substrate used for the microtomed samples precludes unambiguous identification of its mineralogy and the grain was completely destroyed by the SIMS analysis.

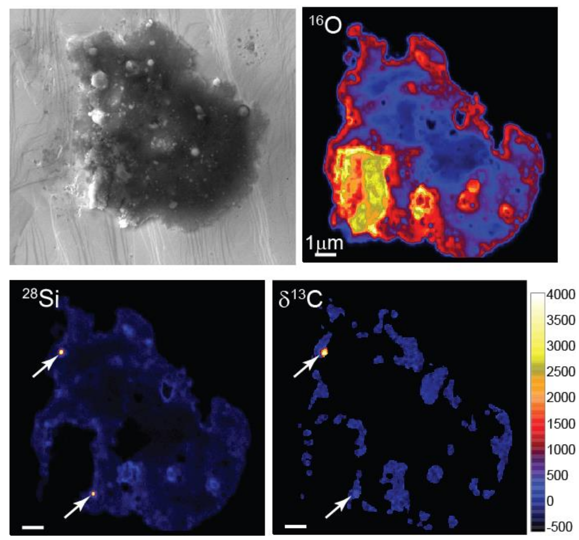

Figure 1: SEM and NanoSIMS images of a fragment of Ryugu sample C0109-2. Arrows indicate two presolar SiC grains with $\delta^{13}C=+4700$‰ (upper) and +600‰ (lower).

Carbon and nitrogen isotopic ratios for the presolar grains are compared to literature data for presolar SiC [5] in Fig. 2A. Silicon data are shown in Fig. 2B; note that two grains from Chamber A microtome sections could not be analyzed for Si due to contamination from the substrate. SiC grains have been divided into different groups reflecting different stellar origins. The Ryugu grains generally plot in the regions of mainstream, AB, and Z grains on Fig. 2A. However, the N isotopic ratios for many are closer to solar and/or terrestrial than the majority of meteoritic SiC grains, most likely reflecting the contribution of N from surrounding organic matter to the grains. Similarly, three grains with $^{12}C/^{13}C$~15 are more likely AB grains ($^{12}C/^{13}C<10$) whose C isotopic measurement contained some organic signals. One grain (#5) can be classified as a Z grain due to its location on the Si 3-isotope plot (Fig. 2B).

We estimated the abundance of presolar SiC in the Ryugu samples by dividing their total cross-sectional area by the total area measured (3900 μm^2 and 4600 μm^2 for Chambers A and C, respectively). For purposes of simplicity, we only considered the pressed particles for the calculation. Although the statistical errors are large, the estimates for the two Chambers are consistent with each other and imply a total SiC abundance of 29 (+16, -11, 1-σ) ppm (Fig. 3).

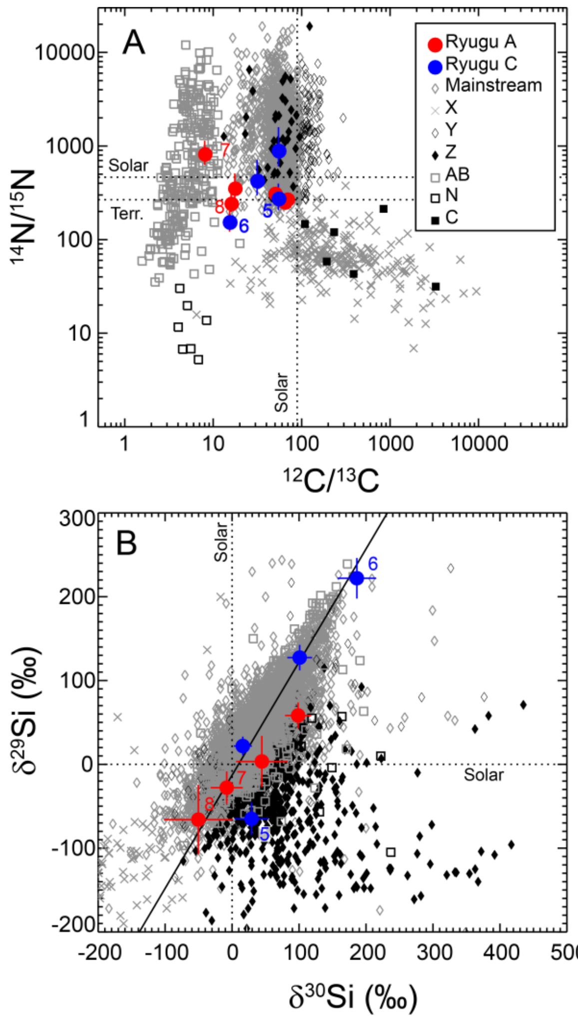

Figure 2: The A) C-N and B) Si isotopic ratios of Ryugu presolar grains are compared to literature data for meteoritic SiC [5]. The solid line in B is best-fit line to mainstream SiC.

Discussion: Mineralogical, petrological, and isotopic data suggest that Ryugu is related to CI chondrites [6]. The inferred abundance of presolar SiC in the Ryugu samples studied here of ~30 ppm is essentially identical to that estimated for CI, CM, and CR chondrites. This result is thus consistent with a Ryugu-CI chondrite connection. Given difficulties in cleanly measuring the isotopic compositions of small SiC grains in situ, the Ryugu grains have isotopic compositions consistent with those seen in SiC grains isolated from primitive meteorites. We note, however, that 4/10 of the identified presolar grains have $^{12}C/^{13}C<20$, whereas ~90% of meteoritic SiC grains have higher ratios. This may suggest an overabundance of highly ^{13}C-rich grains (e.g., AB or N grains) in Ryugu. More likely, due to the ubiquitous presence of organic matter in the samples (which can dilute the isotopic signatures of presolar SiC grains), this reflects a selection bias in that the most anomalous grains are easier to identify in situ. Clearly better statistics are needed and searches for additional presolar grains, both O-rich and C-rich, in the Ryugu samples are planned.

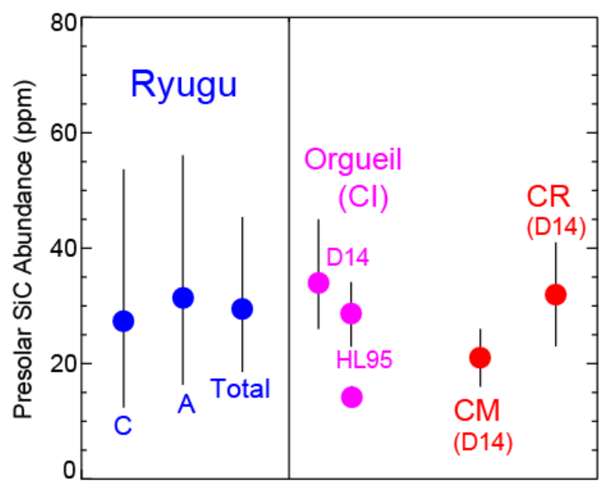

Figure 3. The estimated abundances of presolar SiC in Ryugu Chambers A, C, and total are compared to those of CI, CM, and CR chondrites. D14: [7], HL95: [8].

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References:

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