ISOTOPIC COMPOSITIONS OF NOBLE GASES AND NITROGEN IN THE RYUGU SAMPLES RETURNED BY HAYABUSA2. R. Okazaki[1], B. Marty[2], H. Busemann[3], K. Hashizume[4], J. Gilmour[5], A. Meshik[6], T. Yada[7], F. Kitajima[1], M.W. Broadley[2], D. Byrne[2], E. Füri[2], M.E.I. Riebe[3], D. Krietsch[3], C. Maden[3], A. Ishida[8], P. Clay[5], S. Crowther[5], L. Fawcett[5], T. Lawton[5], O. Pravdivseva[6], J. Park[9,10], K. Bajo[11], Y. Takano[12], K. Yamada[13], S. Kawagucci[14,15], Y. Matsui[14,15], M. Yamamoto[1], Y.N. Miura[16], K. Righter[17], S. Sakai[12], N. Iwata[18], N. Shirai[19], S. Sekimoto[20], M. Inagaki[20], M. Ebihara[21], R. Yokochi[22], K. Nishiizumi[23], K. Nagao[24], J.I. Lee[24], A. Kano[25], M.W. Caffee[26], R. Uemura[27], T. Nakamura[8], H. Naraoka[1], T. Noguchi[1,28], H. Yabuta[29], H. Yurimoto[11], S. Tachibana[30], H. Sawada[7], K. Sakamoto[7], S. Watanabe[27], and Y. Tsuda[7], [1]Dept. Earth Planet. Sci., Kyushu U. (e-mail: okazaki.ryuji.703@m.kyushu-u.ac.jp), [2]Université de Lorraine, CNRS, CRPG, [3]IGP, ETH, [4]Facult. Sci., Ibaraki U., [5]Dept. Earth Environ. Sci., U. Manchester, [6]Phys. Dept., Washington U., [7]ISAS, JAXA, [8]Dept. Earth Sci., Tohoku U., [9]Phys. Sci., Kingsborough Comm. Coll., [10]Dept. Earth Planet. Sci., AMNH, [12]Biogeochem. Res. Center, JAMSTEC, [13]Dept. Chem. Sci. Engr., TITECH,[14]Res. Inst. for Global Change, JAMSTEC, [15]Inst. Extra-cutting-edge Sci. Tech. Avant-garde, Res., JAMSTEC, [16]Earthquake Res. Inst., U. Tokyo, [17]ARES, NASA JSC, [18]Facul. Sci., Yamagata U., [19]Dept. Chem., Tokyo Metropolitan U., [20]Inst. Integ. Rad. & Nucl. Sci., Kyoto U., [21]Dept. Earth Sci., Waseda U., [22]Dept. Geophys. Sci., U. Chicago, [23]Space Sci. Lab., UC Berkeley, [24]Div. Polar Earth-Sys. Sci., KOPRI, [25]Sch. Sci., U. Tokyo, [26]Dept. Phys., Purdue U., [27]Dept. Earth Environ. Sci., Nagoya U., [28]Earth Planet. Sci., Kyoto U., [29]Earth Planet. Sys. Sci. Prg., Hiroshima U., [30]UTOPS, U. Tokyo.

Introduction: In December 2014, the Hayabusa2 spacecraft launched to visit the C-type asteroid (162173) Ryugu to bring back surface and subsurface materials to the Earth. The spacecraft arrived at Ryugu on June 27, 2018, and subsequently carried out two touchdowns (TDs) and sample collections. [1]. The 1st TD was carried out and collected surface samples, while the 2nd TD was done to collect the impact ejecta near the artificial crater made by the Small Carry-on Impactor operation in April 2019 [1]. Samples collected during the 1st and 2nd TDs were stored in Chamber A and C of the Hayabusa2 sample catcher, respectively [2]. Our principal objective is to quantify the indigenous compositions of the Ryugu samples with as little terrestrial contamination as possible. Here we report the isotopic ratios and concentrations of noble gases and nitrogen in the Ryugu samples allocated to the Hayabusa2-initial-analysis-volatile team.

Samples and Experimental method: The samples both from Chamber A (A0105- series) and from Chamber C (C0106- series) were allocated to the volatile sub-team. These samples are typically 0.8 mm-sized individual grains, not clumps of powders. Each of the samples was pressed onto diamond disks and pelletized for the Fourier-Transform Infrared (FT-IR) spectroscopy and Field-Emission Scanning Electron Microscope (FESEM) observations prior to isotope analyses. To avoid contamination from the Earth's atmosphere, we treated the samples under a pure nitrogen environment or in vacuum during the entire procedures from the sample preparation to the isotope analyses [3]. In addition to the pelletized samples, noble gases were analyzed in some fragments generated during the pelletization process. Noble gas analyses were performed at Kyushu U., ETH, U. Manchester, and Washington U., while noble gas and nitrogen isotopes were measured at CRPG-Nancy and Ibaraki U.

Results and Discussion: Twenty-four pelletized samples were measured for FT-IR and FESEM to characterize their petrology and mineralogy. The FESEM observation revealed that all of the Ryugu samples consist of a phyllosilicate-rich fine-grained matrix, with variable amounts of magnetite and Fe-sulfide, which are consistent with the other Ryugu samples allocated to different sub-teams [4, 5], and show similarities with CI chondrites. Reflectance spectra of our samples are also consistent with the previous reports on the Ryugu grains [e.g., 6].

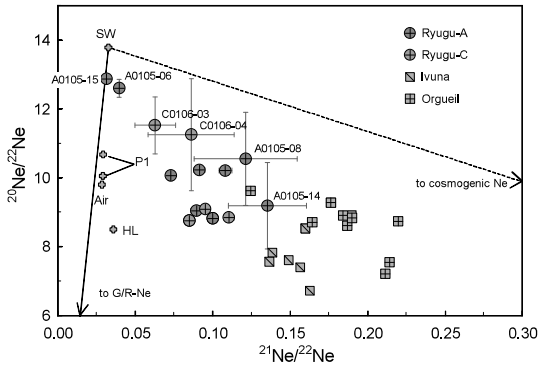

Fig. 1. Isotopic ratios of Ne in the Ryugu samples. Most of the samples contains P1 and HL Ne as the dominant components, while some show a clear solar wind signature and higher concentrations of He and Ne compared to the others.

The modal abundances of magnetite and Fe-sulfide are similar to those of typical CI lithology, which

indicates that our samples are not magnetite or sulfide-rich CI clasts [7], CM, or CY chondrite materials [8].

Isotopic ratios of Ne in the Ryugu samples (Fig. 1) are similar to those in Orgueil and Ivuna [9], and can be explained by a mixing between solar wind (SW) [10], planetary-type Ne (P1 or Q gas: [11, 12]), and presolar HL Ne [12]. Based on the Ne isotopic ratios, we calculated cosmogenic ^{21}Ne concentrations by weighted mean to be 5.0 and 4.6 $\times 10^{-9}$ cm^{3}STP/g for the Ryugu-A (except for SW-rich A0105-15) and for the Ryugu-C samples, respectively. The measured ^{10}Be concentrations [13] suggest shielding depths of 2–20 g/cm^2 (relatively shallow) and one of 150 g/cm^2 (deeper) for the Ryugu-A and C samples, respectively. Based on these measurements in conjunction with the production rates [14] for the CI chemistry [15], we obtained the cosmic ray exposure ages of 5.6 and 5.7 Myr for the Ryugu-A and C samples, respectively. For the SW-rich A0105-15, we assumed the shallowest shielding of 0–1 g/cm^2 and obtained several hundreds of kyr using its cosmogenic ^{21}Ne of 1.1×10^{-9} cm^{3}STP/g. We concluded that most of the Ryugu materials resided at a subsurface layer of Ryugu beneath an uppermost layer of material that have been exposed to solar wind irradiation.

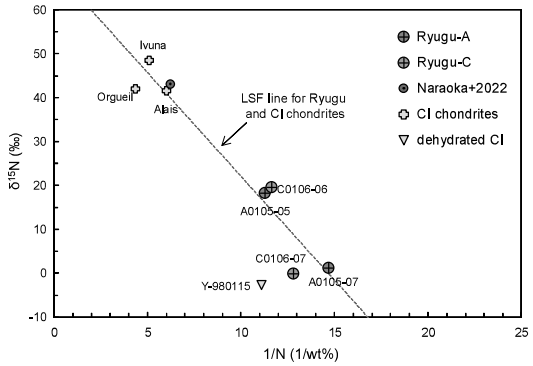

Fig. 2. Isotopic ratios and concentrations of nitrogen in the Ryugu samples. Our Ryugu samples are depleted in nitrogen with low δ^{15}N ratios compared to the other sub-team's Ryugu sample [16] and CI chondrites. A dehydrated CI chondrite Yamato (Y-) 980115 [19] also has a low nitrogen concentration and a low δ^{15}N value.

Isotopic ratios of nitrogen in our samples are depleted in ^{15}N compared to those in the other sub-teams' Ryugu samples [16, 17] and CI chondrites [e.g., 18] (Fig. 2). The nitrogen concentrations are also lower than those in CI chondrites and the other Ryugu samples. The two samples of A0105-07 and C0106-07 plot close to the Yamato-980115 dehydrated CI chondrite [19]. The variations observed in the δ^{15}N and the nitrogen contents can be attributed to sample heterogeneity at a small scale of samples, and suggest that there are at least two different carrier phases of nitrogen in the Ryugu samples; one is nitrogen-depleted and has a lower δ^{15}N value, while the other is nitrogen-enriched and has a higher δ^{15}N value. A linear trend is observed among the Ryugu samples and CI chondrites, from which we can estimate the δ^{15}N value to be ~70 ‰ for the ^{15}N-rich end member. The similarity with the dehydrated CI chondrite Y-980115 suggests that some dehydration or devolatilization effect may be responsible for the depletion of the ^{15}N-rich phase from our samples, although the mineralogy of the Ryugu samples does not show heavily metamorphosed features as Y-980115 does.

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