NEUTRON ACTIVATION ANALYSIS OF ROCKY GRAINS RECOVERED BY THE HAYABUSA SPACECRAFT-REVISITED M. Ebihara[1], S. Sekimoto[2], N. Shirai[1], T. Nakamura[3], A. Tsuchiyama[4], M. Abe[5], A. Fujimura[5], T. Mukai[5] and T. Yada[5]. [1]Department of Chemistry, Tokyo Metropolitan University, Hachioji, Tokyo 192-0397, Japan (ebihara-mitsuru@tmu.ac.jp), [2]Kyoto University Research Reactor Institute, Kumatori, Osaka, Japan, [3]Department of Earth and Planetary Material Sciences, Tohoku University, Sendai, Japan, [4]Department of Earth and Space Science, Osaka University, Toyonaka, Japan, and [5]ISAS/JAXA, Sagamihara, Kanagawa, Japan.

Introduction: The Hayabusa spacecraft was launched on May 9, 2003 and reached an asteroid Itokawa (25143 Itokawa) in September 2005. The spacecraft tried to collect the surface material of Itokawa by touching down to the asteroid in November. The spacecraft was then navigated for the earth and finally returned to the earth on June 12, 2010. After careful and extensive examination of the sample catcher, more than 1500 particles were recognized visibly by microscopes, most of which were eventually judged to be extraterrestrial, higly probably originated from Itokawa [1]. Soon after such an examination, initial analyses were started by scientific teams organized for initial examination of the returned samples from Itokawa. Scientific results on these grains were presented at LPSC last year and some of them were published in *Science* in last August [2-9].

As a part of the initial analysis, we conducted bulk chemical analysis of a tiny single grain by using instrumental neutron activation analysis (INAA). Our result was included in the *Science* issue [4]. We again performed a similar experiment for additional two grains as the second run of the initial analysis and will present the analytical results on these grains here.

Samples: Two rocky grain samples (RA-QD02-0064 and RB-QD04-0049) were chosen for this study. RA-QD02-0064 (hereafter, A0064), which was recovered from the chamber A of the sample catcher, was one of the samples used for the first run of the initial analysis. RB-QD04-0049 (hereafter, B0049) was recovered from the chamber B and newly released for second run of the initial analysis. A0064 consists mosltly of olivine whereas B0049 is composed of olivine, plagioclase, pyroxe and Ca-phosphate. Both samples are about 50 μm x 50 μm in size. In the following discussion, the previous results for RA-QD02-0049, which were alreasy published [4], are referred as A0049.

Analytical procedure: For bulk chemical analysis, conventional INAA was applied. Before assaying to INAA, rocky grain samples were inspected by X-ray tomography by using high density X-ray beam at the X-ray syncrotron facility (Spring-8). After X-ray analysis, the grains were moved to Kyoto University Reactor Research Institute (KURRI). Each grain sample was placed into a pit (1 mm ϕ) of clean synthesized quartz disk (10 mm ϕ), which was covered with a plane quartz disk (10 mm ϕ). As the grains analysed for this time (A0064 and B0049) were small (actually, much smaller than A0049 analyzed at the first run last year), each grain was placed on the pit bottom by resin (glycol phthalate). An assembly of quarts plates with a grain in-between was wrapped with pure Al foil. The samples was irradiated for 27 h by reactor neutrons at KURRI. Thermal neutron flux was 8.2 x 10^{13} $cm^{-2}s^{-1}$ with Cd raio of about 3.9. Soon after the irradiation, the sample assembly was opened and each grain sample was transferred into a pit of a new (unirradiated) quartz disk, which was covered by another quartz disk and then wrapped with Al foil for gamma-ray measurement. In transferring the grains, resin couldn't completely be removed. Forthermore, a part of quatz needle used for assisting a grain was sticked to A0064 with a small amount of resin.

The gamma-ray measurement was done at KURRI by using Ge detector. For quantification, three reference standard samples (basaltic reference samples JB-1, the Smithsonian Allende powder and Fe_2O_3) were used. We confirmed reasonable consistency in analytical data by using either JB-1 or Allende as a reference standard.

Result and discussion: A total of 15 elements (Na, K, Sc, Cr, Mn, Fe, Co, Ni, Zn, La, Ce, Nd, Sm, Eu and Au) were determined. Figure 1 compares elemental abundances for 10 elements out of them. Data are plotted after Fe- and CI-normalization. B0049 has two data denoted B0049-1 and B0049-2, because the B0049 grain was splited into two portions when transferring the sample into a new sample holder after neutron activation. In fig. 1, In addition to new data for A0064 and B0049, the data for previously analyzed A0049 are plotted for comparison. Data for the olivine separate from the St. Severin chondrite [10,11] also are shown. There appears a large difference in Fe- and CI-normalized vaues for Cr, Au, K and Na between the two B0049 samples. As this sample contains plagioclase, relatively high contents of Na and K in B0049-2 can be explained if plagioclase is dominant in B0049-2. Anmalously high content of Au in this sample cannot be explain by the presence of plagioclase. Au was be-low the detection limit for B0049-1 and also for A0049 at the 1st run. We suspect that B0049-2 was contaminated with Au. A similarly high content of Cr was observed for B0049-2. Although no significant amount of chromite was confirmed for this grain by X-ray tomography, tiny chromite grains may be present inside the grain B0049-2. This could explain relatively high content of Zn for this grain. Except for these five elements shown in Fig. 1, similar abundances can be seen for the two B0049 samples.

In comparing abundance data for A0064 and B0049, similar abundances can be noticed for Sc, Ni, Co, Fe, Mn and possible K. These abundances are also similar to those for A0049 except for Co. As seen in Fig. 1, A0064 and B0049 are more depleted in Co compared with A0049-1 and A0049-2, where Ni and Co content ratios are essentially chondritic. Two B0049 samples and A0064 show similarly low Co/Ni ratios. Such an extreme fractionation can be seen in taenaite and terta-taenite metal phases [12]. Metal grains were not observed in these grains by X-ray tomography. A large fractionation of Ni and Co in A0064 and B0049, and high abundances of Cr and Zn in B0049-2 remain unanswered for their mechnisms.

Five rare earth elements (REEs) (La, Ce, Nd, Sm and Eu) were determined for B0049. Because this grain contains Ca-phosphate minerals, we may expect to have reasonably high contents of REEs for this sample. Obtained values were too high to be exlained by the presence of Ca-phophate. In fact, abudnaces for light REEs are much higher that those in Ca-phosphate separates from oridinary chondrites [13]. Extremely high contents, especially for light REEs, and an apparent positive anomaly for Ce make us suspect that the sample was contaminated with such REEs.

Figure 2 shows FeO/Sc vs. FeO/MnO for a variety of geochemical and cosmochemical samples. FeO/Sc ratios are relatively low for silicate materials of differentiated asteroids and planets like HED (4 Vesta?), Earth, Moon and Mars because considerable amount of Fe is separated into metallic core, yielding relatively lower FeO/Sc ratios in silicates. Two Itokawa grain samples A0064 and B0049, for which three solid circles are indicated in Fig. 2, have relatively high FeO/Sc ratios, which are similar to those for olivine separates from ordinary chondrites. This figure clearly shows that the two rocky grains analyzed in this study are extraterrestrial in origin and are similar to olivine in ordinary chondrites.

References: [1] Nakamura T. et al. (2011) *LPS XXXXII*, Abstract #1766. [2] Nakamura T. et al. (2011) *Science, 333*, 1113-1116. [3] Yurimoto H. et al. (2011) *Science, 333*, 1116-1119. [4] Ebihara M. et al. (2011) *Science, 333*, 1119-1121. [5] Noguchi T. et al. (2011) *Science, 333*, 1121-1125. [6] Tsuchiyama A. et al. (2011) *Science, 333*, 1125-1128. [7] Nagao K. et al. (2011) *Science, 333*, 1128-1131. [8] Kitajima F. et al. (2011) *LPS XXXXII*, Abstract #1855. [9] Naraoka H. et al. (2011) *LPS XXXXII*, Abstract #1672. [10] Mason B. and Graham A. L. (1970) *Smithson. Contrib. Earth Sci. 3*, 1-17. [11] Rubin A. E. (1990) *Geochim. Cosmochim. Acta, 54*, 1217-1232. [12] Kong P. and Ebihara M. (1997) *Geochim. Cosmochim. Acta, 60*, 2667-2680. [13] Ebihara M. and Honda M. (1984) *Earth Planet. Sci.*, 63, 433-445.

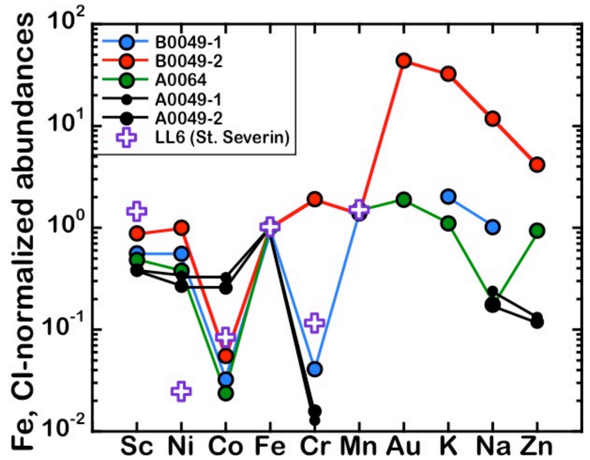

Fig. 1. Elemental abundances of some elements determined for Hayabusa grains A0064 and B0049 (-1 and -2). Individual data are normalized to CI and Fe values. Data for A0049 (1- and 2-) as well as olivine separates from St. Severin LL chondrite are also shown for comparison.

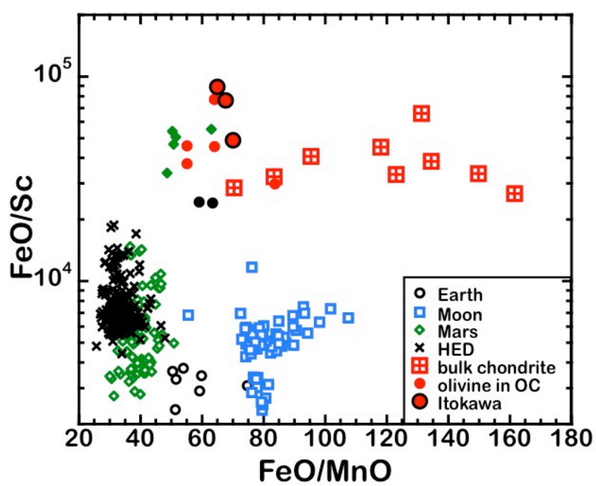

Fig. 2. Abundance ratios of FeO/Sc compared with FeO/MnO for terrestrial and extraterrestrial materials. Small solid symbols represent olivine from Earth, Mars and ordinary chondrites.