Japan Geoscience Union Meeting 2012
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PPS22-P01 Room:Convention Hall Time:May 25 11:45-12:15

On the location of the Yamato 00 meteorites

IMAE, Naoya[1*], Naoyoshi Iwata[2], Yasuyoshi Shimoda[3]

[1]National Institute of Polar Research, [2]Yamagata University, [3]Ariake Junior High School

Search for meteorites on the bare icefield around Yamato Mountains were carried out by Japanese Antarctic Research Expedition (JARE-41), Nov. 2000 -Jan 2001, and collected ˜3500 meteorites with the total weight of ˜200 kg. Many large and unique meteorites are included in the Yamato 00 collection, such as the largest nakhlite (Yamato 000593), a large iron meteorite (Yamato 000378), a large diogenite (Yamato 002875), lherzolitic shergottites (Yamato 000027, Yamato 000047, and Yamato 000097), and so on.

Recovery position of each Antarctic meteorite is one of the basic field data and indispensable for the study of the meteorite concentration mechanism in Antarctica. However, the study is not enough. Although Global Positioning System (GPS) is useful for the recording the location, the member on snowmobile recorded collected time. Locations were recently recovered based on the trajectory of GPS on board in a large snow vehicle used for navigation during the meteorite search. The recovered locations show that large insufficiently searched area in icefields is remained around the Yamato Mountains.

Keywords: Yamato 00 meteorites, search for meteorites, Antarctica, bare icefield, Japanese Antarctic Research Expedition, Yamato mountains

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Ultra-sensitive noble gas analysis system for return samples from the solar system

OKAZAKI, Ryuji[1*]

[1]Kyushu University

Isotopic compositions of terrestrial and extraterrestrial materials are important to understand the formation and evolution of the solar system materials and bodies, since they are contributed by some processes such as radioactive decay, mass fractionation, and isotope exchange. Noble gases are most sensitive to such isotopic effects because of the extreme depletion in solid materials. In extraterrestrial materials, He and Ne are dominated by isotopes that originate from solar wind implantation, spallation/n-capture reactions, and radioactive decay ($^{235,\ 238}$U and ^{232}Th). Heavy noble gases, Ar, Kr, and Xe are mixtures of products from stellar nucleosynthesis (s-, r-, and p-processes), radioactive decay (^{40}K, $^{128,\ 130}$Te, ^{238}U, ^{232}Th, ^{244}Pu, and ^{129}I), and spallation/n-capture reactions, in addition to primordial (planetary) gas. Hence, the noble gas isotopes reflect many processes and should be a useful tool for cosmochemistry and geochemistry.

Because of their low abundances in solid planetary materials, extremely high sensitivity is necessary for a noble-gas analyzer. In order to measure microgram- or sub-microgram samples returned by space explorations, I have been constructing a new ultra-sensitive mass spectrometry system at Kyushu Univ. The system is a combination of a conventional mass spectrometer that consists of a magnetic sector-type MS with a Neir-type ion source), and a resonance ionization mass spectrometer (RIMS) that consists of a resonance ionization ion source and a time-of-flight (TOF) MS.

The conventional MS is useful to measure all noble gases (He, Ne, Ar, Kr, and Xe) with a detection limit of around 5000 atoms. Helium and Ne in Antarctic micrometeorites (around 0.5 microgram in weight) have been measured using a small resistant furnace (called Pot-pie furnace). Return samples from asteroid and lunar regolith should contain amounts of solar-wind He and Ne of which isotopic ratios and concentrations would reflect the regolith history.

The RIMS is designed to measure extremely small amounts of Kr and Xe ($>$100 atoms), referring to RELAX (Refrigerator Enhanced Laser Analyzer for Xenon) developed by Dr. J. D. Gilmour and his colleagues. The RIMS at Kyushu Univ. is equipped with a dye laser system (TII Tokyo Instruments Inc.) that generates 3.5 mJ per pulse (8 nsec of pulse width) at 216 and 256 nm of wavelengths applied for ionization of Kr and Xe, respectively. The power densities of the UV lights are probably high enough to ionize Kr and Xe with almost unit probability when focused to be $<$0.01 cm in diameter in the ion source. Ionization efficiencies and ion transmissions will be investigated. The RIMS enables to apply many radiometric dating (such as I-Xe, Te-Xe, and Pu-Xe) and Kr-Kr dating that will be very interesting for samples experienced cosmic-ray exposure.

For gas extraction from samples, the analysis system is equipped with a pulse Nd:YAG laser in addition to the furnace (Pot-pie). The Nd:YAG laser produces 200 mJ per pulse (10 nsec) at 1064 nm. The focused beam has a diameter of 50 micrometer and will create the plasma plume. The plasma lights have wavelengths that depend on the chemical composition of fused area of the sample, and are measured using a LIBS (Laser-induced Breakdown Spectroscopy) system. Using the LIBS system, the fused mass can be calculated by measuring the major element abundances. Also, potassium contents will be determined for micro-area K-Ar dating.

The RIMS and LIBS systems are now under construction, and the progress will be reported.

Keywords: return sample, noble gas

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The JAMSTEC NanoSIMS 50L: Imaging mass spectrometry at the sub-micron scale for meteorite and biology samples

ITO, Motoo[1*]

[1]Kochi Institute for Core Sample Research, JAMSTEC

On November 4, 2011 the Cameca NanoSIMS 50L ion microprobe was delivered to Kochi Institute for Core Sample Research. The NanoSIMS is *the-state-of-the-art* instrument for microanalysis by a secondary ion mass spectrometry. The strong ability is to analyze extremely small *regions-of-interest* (achieving lateral resolutions down to 50 nm and small sputtering depth) while keeping very high sensitivity at high mass resolution. This derives from the new coaxial optical design of the primary ion sources and secondary ion extraction system, and from a new design of the magnetic sector mass analyzer. The capability of simultaneously measurement up to 7 masses, achieving more precise isotopic ratios from the same small volume, or better ion image superimposition in a imaging mode. This allows the comparison of images of the distribution of different measured isotopes or elements. This ability for imaging with sub-micro meter spatial resolution is very unique to the NanoSIMS and provides a new approach to the analysis of the isotope and/or element distributions in variety of samples. Faraday cups are also installed into the NanoSIMS, enabling to achieve the precision and external reproducibility of isotopic measurements down to the sub-permil level. Therefore, the JAMSTEC NanoSIMS will be the centerpiece of the ion imaging and geomicrobiology laboratories at the Kochi Institute for Core Sample Research and will be used to investigate extraterrestrial, terrestrial and biology samples (e.g., meteorites, oceanic crusts, deep life) explored by a scientific ocean drilling and sample-return missions from extraterrestrial locations opportunities.

The NanoSIMS instrument is in a clean room with class 10,000. Temperature (+- 0.3^{o}C around a magnet) and humidity level (+-2% in the room) are well controlled. Currently the specifications of beam size (Cs+: ˜30 nm, O-: 180 nm) and beam stability in 10 min (Cs+: 0.2 %, O-: 0.7 %) were achieved. We have done with Si and O isotopic measurements using electron multipliers and Faradays cups for Si wafer and quartz, respectively (Table 1).

Some initial results for O and Mg isotopes in meteorites and terrestrial mineral standards, and isotope images of microbiology sample will be shown at the meeting.

Acknowledgements: Funding for the JAMSTEC NanoSIMS ion imaging laboratory was provided by the Leading-edge Research Infrastructure Program of the Ministry of Education, Culture, Sports, Science and Technology and Japan Society for the Promotion Science.

Keywords: NanoSIMS, Ion imaging, sub-micron spatial resolution

Table 1. Reproducibilities of Si and O isotopic measurements.

EMs		16 points (within 1 inch sample)	10 points (5 sample locations)	FCs		10 points (within 1 inch sample)	10 points (5 samples locations)
$^{29}Si/^{28}Si$	Si wafer	+- 0.7 permil	+- 0.9 permil	$^{29}Si/^{28}Si$	Si wafer	+- 0.07 permil	+- 0.13 permil
$^{30}Si/^{28}Si$	Si wafer	+- 0.7 permil	+- 1.1 permil	$^{30}Si/^{28}Si$	Si wafer	+- 0.17 permil	+- 0.26 permil
				$^{18}O/^{16}O$	Quartz	+- 0.6 permil	+- 0.5 permil

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Ion microprobe analyses of Mg isotopes in hibonite inclusions from Murchison meteorite

SASAKI, Shogo[1], HIYAGON, Hajime[1*], FUJIYA, Wataru[1], TAKAHATA, Naoto[2], SANO, Yuji[2], MORISHITA, Yuichi[3]

[1]Graduate School of Science, The University of Tokyo, [2]Atmosphere and Ocean Research Institute, The University of Tokyo, [3]Geological Survey of Japan, AIST

Hibonite (CaAl12O19) is one of the most refractory minerals, which condense from the solar nebula at highest temperatures, and hence, hibonite-bearing refractory inclusions may have important information in the earliest history of the solar system. In fact, PLACs (PLAty hibonite Crystals) and BAGs (Blue AGgregates) (Ireland, 1988) show large isotopic anomalies in Ca and Ti, and low inferred initial 26Al/27Al ratios. It is suggested that they might form BEFORE injection of 26Al into the solar system (Liu et al., 2009). In order to better understand earliest evolution of the solar system materials, we recovered about ˜30 of hibonite-bearing inclusions from the Murchison (CM2) meteorite and Mg isotopic compositions were analyzed for 5 SHIBs, 5 PLACs, 1 Blue Spinel (Ireland et al., 1986), and 2 F-inclusions (see below) using two Secondary Ion Mass Spectrometers, NanoSIMS 50 (at AORI, University of Tokyo) and ims-1270 (at AIST, Tsukuba).

Results: Inferred initial 26Al/27Al ratios for SHIBs are (4.7 +/- 1.0)x10E-5, consistent with the canonical ratio for normal CAIs (MacPherson et al., 1995; Jacobsen et al, 2008). On the other hand, PLACs and a Blue Spinel show no resolvable excesses in 26Mg so that their initial 26Al/27Al ratios are zero within errors. Among them, Delta-26Mg for all the data of 5 PLACs are slightly negative (i.e., apparent deficits in 26Mg), suggesting possible isotopic anomalies in Mg isotopes. These results are consistent with previous works (e.g., Liu et al., 2009). In addition to these inclusions, we found two inclusions with heavily fractionated Mg isotopes (up to $>$50 permil/amu), and here we call them as F-inclusions (F means Fractionation). They also show initial 26Al/27Al ratios of ˜0 within errors, indicating some relations to so called FUN inclusions (Lee, 1988). In order to produce such large isotopic mass fractionation of Mg, evaporation must occur from the molten state, and in the condition without back reactions (e.g., evaporation under vacuum). Large mass fractionation of Mg in spinel suggests that spinel was not present as a solid phase at least during the early stages of evaporation, so that the temperature must be ˜1600C or higher (Stolper, 1982) during the evaporation event, which resulted in extensive loss ($>$95%) of Mg (Richter et al., 2007).

References: Ireland (1988) Geochim. Cosmochim. Acta 52, 2827-2839; Liu et al. (2009) Geochim. Cosmochim. Acta 73, 5051-5079; Ireland et al. (1986) Geochim. Cosmochim. Acta 50, 1413-1421; MacPherson et al. (1995) Meteoritics 30, 365-386; Jacobsen et al. (2008) Earth Planet. Sci. Lett. 272, 353-364; Lee (1988) In: Meteorites and the Early Solar System. (eds., Kerridge and Matthews), p1063-1088; Stolper (1982) Geochim. Cosmochim. Acta 46, 2159-2180; Richter et al. (2007) Geochim. Cosmochim. Acta 71, 5544-5564.

Keywords: hibonite, refractory inclusion, ion microprobe, Mg isotopes, isotopic fractionation, Murchison meteorite

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Two types of orthopyroxene in a micrometeorite

MIYAKE, Akira[1*], IMAE, Naoya[2]

[1]Kyoto Univ., [2]National Institute of Polar Research

[Introduction]

Four stable pyroxene polymorphs have been identified: Ca-rich clinopyroxene (Ca-rich Cpx, space group: C2/c), Ca-poor clinopyroxene (pigeonite) (Ca-poor Cpx, C2/c or P2_1/c), protoenstatite (Pen; Pbcn), and low-temperature orthopyroxene (LT-Opx, Pbca). Moreover, Ohi et al. (2008, 2010) established the stability field of high-temperature orthopyroxene (HT-Opx, Pbca) in enstatite (Mg2Si2O6) - diopside (CaMgSi2O6) system. However, LT- and HT-Opx have never been reported in natural sample. Micrometeorite which has about 100 um in size is collected from the ice in Antarctica. The most of them is like to be condritic meteorite and consistent with olivine, pyroxene and so on. Two types of Opx which have the different chemical composition although the same space group (Pbca) are found in a micrometeorite, TT001c5-48.

[Methods]

Major elements in the micrometeorite were analyzed using an electron probe microanalyzer (EPMA) and the phase of pyroxene was investigated using a Raman spectroscope. Thereafter, the specimen for transmission electron microscope (TEM) was made using a focused ion beam (FIB) and microtextures and electron diffraction patterns were obtained using a TEM.

[Result and Discussion]

Two types of pyroxene, which have a little different Wo content, were observed from EPMA and both of pyroxenes have the Ca-poor rim. Moreover, these pyroxenes have more Mn component than other micrometeorite. Raman spectra from these pyroxenes have almost same and indicate Opx with Pbca symmetry according to Wang et al. (2001). Electron diffraction patterns show that both phases have Pbca and no microtextures are obseverd in both cores of these pyroxene. On the other hand, both rims have the micro twin. These results suggests that two types of Opx with a little different Wo content are LT- and HT-Opx.

Keywords: orthopyroxene, micrometeorites, FIB-TEM

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Estimation of space weathering rates based on reflectance spectra of a regolith-breccia meteorite

MISU, Takaaki[1*], NAKAMURA, Tomoki[1], SASAKI, Sho[2], HIROI Takahiro[3]

[1]Graduate School of Science, Tohoku University, [2]RISE Project, National Astronomical Observatory of Japan, [3]Department of Geological Sciences, Brown University

Space weathering is the term used for color alternation of asteroid surfaces from light to dark. This results from micrometeorite bombardment and cosmic-ray exposure, which generates metallic Fe nano-particles in the outermost layer of mineral particles at the asteroid surfaces. Because of space weathering, reflectance spectra of ordinary chondrites slightly differ from those of S-type asteroids that are parent bodies of ordinary chondrites. Therefore, when we establish the asteroid-meteorite connection based on the reflectance spectra, we must consider the effect of space weathering. Regolith breccia Tsukuba H chondrite is affected by space weathering on the asteroid surface of its parent body and shows characteristic dark-light structure. The dark portion is heavily weathered because of exposure to solar winds on the asteroid surface, while the light portion is not weathered because it was buried inside of the asteroid. Therefore the dark portion contains large amounts of cosmogenic and solar-wind derived noble gases, but the light portion is depleted in such noble gases.

In this study I compared dark potions and light potions of the Tsukuba meteorite in terms of mineralogy and reflectance spectra and investigated space weathering effects on this meteorite. Electron probe micro-analyzer (EPMA) analysis revealed that mineral chemistry of the dark potions and the light potions are the same. I applied the reflectance spectrometer for obtaining diffuse reflectance spectra of both dark and light potions. For comparison of the reflectance spectra, MGM (Modified Gaussian Model) is used. The results indicate that the band strength and areas of spectra derived from the dark potions are much lower than those of spectra from the light potions. Using the band strength and areas as parameters, we evaluate space weathering rates of S-type asteroids based on changes in reflectance spectra and cosmic-ray exposure ages of the Tsukuba meteorite. We use calculated results of cosmic-ray exposure age of the Tsukuba meteorite reported in a previous work. Applying the space weathering rates determined in this study to the reflectance spectra of S-type asteroids, we may be able to obtain surface ages of the asteroids only from reflectance spectra, which will greatly contribute to decipher the origin and evolution of asteroid belt in the solar system.

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Hydrothermal experiment of melilite and plagioclase: Implication for formation of nepheline in meteorite parent bodies

ICHIMURA, Shun[1*], SETO, Yusuke[1], TOMEOKA, Kazushige[1]

[1]Kobe Univ. Sci

Nepheline ($NaAlSiO_4$) in Ca-Al-rich inclusions (CAIs) and chondrule mesostasis of carbonaceous chondrite is believed to be a secondary altered mineral replacing melilite or plagioclase. Recent studies reported that the nepheline formation is correlated with hydro-thermal process on their parent body, but its detailed condition is not yet established.

To understand the formation process of nepheline in chondrite parent bodies, we conducted hydrothermal alteration experiments. As starting material, we prepared synthetic pure Ca-rich melilite (gehlenite, $Ca_2Al_2SiO_7$), mixture of gehlenite and SiO_2, Mg-contained melilite ($Ca_2AlMg_{0.5}Si_{1.5}O_7$), and plagioclase ($Na_{0.5}Ca_{0.5}Al_{1.5}Si_{2.5}O_8$). Hydrothermal alteration experiments were performed with a teflon reaction cell. The experiments were carried out at temperature of 200 ^oC for run duration of 168 hours, with different pH condition (0, 7, 13, 14) and different water/rock ratios. Na+ concentration in all solution is maintained at 1 mol/l. Run products were identified by powder X-ray diffraction (XRD) and scanning electron microscopy (SEM).

Under pH 14 condition, nepheline hydrate ($NaAlSiO_4H_2O$) and analcime ($NaAlSi_2O_6H_2O$) were observrd in gehlenite-SiO_2 system. Under pH 13-7 conditions, analcime formed by replacing gehlenite or plagioclase. Under pH 0 condition, no crystalline phase was formed from gehlenite and plagioclase. In addition, these alterations proseed under relatively low water/rock ratio condition.

The results indicate that the alteration process of gehlenite and plagioclase strongly depends on pH and water/rock ratio, suggesting that in carbonaceous chondrite parent body aqueous alteration of gehlenite and plagioclase occurred under high pH and lower water/rock ration.

Keywords: nepheline, aqueous alteration, hydrothermal experiments, carbonaceous chondrites

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Stability of Amino Acids and Their Precursors (Hydantoins) against UV Light and Its Relevance to Origins of Life

Palash Kumar Sarker[1*], Jun-ichi Takahashi[2], Yumiko Obayashi[1], Takeo Kaneko[1], Hajime Mita[3], Kensei Kobayashi[1]

[1]Yokohama National University, [2]NTT Microsystem Integration Laboratories, [3]Fukuoka Institute of Technology

It is suggested that life on Earth could have been seeded by the delivery of organics from outer space during the intense bombardment period of primitive Earth. A large number of amino acids and their precursors have been detected in the extracts of carbonaceous chondrites, but their origins and original structure in the chondrites still remain controversial. Numerous simulation experiments have also suggested that these bioorganic compounds were formed from possible interstellar media by irradiation with high-energy particles or ultraviolet (UV) light. Furthermore, organics including amino acids and their precursors in inner part of comet and meteorites are safe from UV light, but organics in interplanetary dust particles (IDPs) are fully irradiated with strong solar UV as well as high-energy particles near Earth orbit. Thus, it is of interest to investigate how these organic compounds alter or survive against UV radiation. In this study, we examined the stability and photolysis products of hydantoin (Hyd) and its 5-substituted molecules, such as 5-methylhydantoin (M-Hyd), 5,5-dimethylhydantoin (DM-Hyd), 5-ethylhydantoin (E-Hyd), 5-ethyl-5-methylhydantoin (EM-Hyd). When 5-substituted hydantoins (EM-Hyd, E-Hyd, DM-Hyd and M-Hyd) were irradiated with UV light, Hyd (a precursor of glycine) was formed as major photolysis products. Therefore, it is assumed that 5-substituted hydantoins in extraterrestrial bodies were possible glycine precursors. Considering the photostability factor, EM-Hyd (precursor of isovaline) was less stable than isovaline aginst UV, though EM-Hyd is generally more stable than isovaline aginst radiation.It is due to the fact that isovaline has larger abosorption coefficient in UV region than EM-Hyd. The present experimental results may point out the potential importance of the photochemistry of isovaline, glycine and their precursor molecules (i.e., hydantoin and 5-substituted hydantoins) in Solar System bodies.

Keywords: Hydantoins, Radiation, Ultraviolet, Photolysis, Isovaline, Glycine