Japan Geoscience Union Meeting 2014
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PPS22-P01 Room:Poster Time:May 1 18:15-19:30

# Laboratory impact experiments of rock projectiles onto simulated asteroid regolith: Impactor fragmentation and capture

NAGAOKA, Hiroki[1] ; NAKAMURA, Akiko[1*] ; SUZUKI, Ayako[2] ; HASEGAWA, Sunao[2]

[1]Graduate School of Science, Kobe University, [2]Institute of Space and Astronautical Science

We conducted laboratory impact experiments of rock projectiles onto target consist of silica sand used as simulated regolith surface. We investigate the relationship between degree of projectile fragmentation and impact velocity and particle size of silica sand.

Laboratory impact experiments have been performed to study the degree of target fragmentation, however, much less attention has been paid to the fate of the impactors. Experiments with impact velocity lower than 1 km/s were conducted using a powder gun and a gas gun at Kobe University, while experiments with higher impact velocity up to 5 km/s were conducted using a two-stage light-gas gun at Institute of Space and Astronautical Science. We collected the projectile fragments in the sand and weighed the mass of the largest fragments.

Destruction of rock projectiles is found to occur when the peak pressure is about equal to the dynamic tensile strength of the rock in the low velocity impact experiments (Nagaoka et al., 2014, MAPS). The largest fragment mass fractions in the high velocity impact experiments are higher than the expected from the result of low velocity impact experiments. The discrepancy is larger for the target with smaller silica sand particles. The larger fragments consist of multiple fragments and silica sand particles which were consolidated into larger particles by compression and the heating due to compaction of silica sand.

Keywords: meteorites, impact process, asteroids

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# Secondary Ion Mass Spectrometry (SHRIMP) U-Pb dating of Chelyabinsk meteorite

KAMIOKA, Moe[1*] ; TERADA, Kentaro[1] ; HIDAKA, Hiroshi[2] ; KIMURA, Kosuke[2] ; SKUBLOV, Sergey[3]

[1]Osaka University, Department of Earth and Space Science, [2]Guraduate school of Science, Hiroshima University, [3]Institute of Precambrian Geology and Geochronology,

On Feburuary 15,2013, a meteorite fell into the area of Chelyabinsk in Russia .The petrographic and chemical analysis of the Chelyabinsk meteorite unambiguously classifies it as an LL5 ordinary chondrite (Galimov et al.2013). The reported Sm-Nd age of 3.7 Ga and Rb-Sr age of 0.29 Ga suggest that the Chelyabinsk meteorites could have suffered from the secondary event possibly due to shock metamorphism.For further understanding of the thermal history of Chelyabinsk meteorite, we carried out an in-situ U-Pb dating of phosphates of which closure temperatures is high (~600 ℃), using Hiroshima-SHRIMP.(Sensitive High-Resolution Ion MicroProbe).

Keywords: Chelyabinsk meteorite, SHRIMP, phosphate, U-Pb dating

PPS22-P03 Room:Poster Time:May 1 18:15-19:30

# Crystallization and subsolidus processes of the NWA 6704 ungrouped achondrite

TAKAGI, Yasunari[1] ; NOGUCHI, Takaaki[1*] ; KIMURA, Makoto[1] ; YAMAGUCHI, Akira[2]

[1]Ibaraki University, [2]National Institute of Polar Research

Introduction: NWA 6704 is an unique ungrouped achondrite. It consists of low-Ca pyroxene, less abundant olivine and plagioclase, minor chromite and merrilite, and trace awaruite, heazlewoodite, and pentlandite (1, 2). Although its bulk oxygen isotopic ratio is within the ranges of the acapulucoite-lodranite and CR chondrites, its petrography and mineralogy are evidently different from both of them (1). The U-Pb dating of this meteorite gives a $^{207}Pb/^{206}Pb$ date of 4563.75 +/- 0.41 Ma (3). To deduce its formation processes is important to understand formation of its parent body that may have predated the formation of chondrite parent bodies.

Methods: Polished thin sections were investigated by optical microscopes, electron microprobe analyzer (EPMA), field-emission scanning electron microscope (FE-SEM), Raman spectroscopy, and electron backscattered diffraction (EBSD).

Results: The most abundant mineral in NWA 6704 is orthopyroxene containing blobs of augite. Both Raman spectroscopy and EBSD data indicate that this pyroxene is orthopyroxene. The texture of the blob-bearing orthopyroxene is very similar to Kintokisan-type orthopyroxene (inverted pigeonite) (4). We call it early formed (ef-) pigeonite. There are another less abundant low-Ca pyroxenes: augite blob-free orthopyroxene, and pigeonite containing sub-micrometer-size augite exsolution lamellae. Here we call them primary orthopyroxene and later formed (lf-) pigeonite. Lf-pigeonite occurs as coherent overgrowth of the primary orthopyroxene and discrete grains in the interstices of large ef-pigeonite. Lf-pigeonite also occur as inclusions in olivine. Based on the EBSD data, modal abundances of ef-pigeonite, olivine, lf-pigeonite, primary orthopyroxene, feldspar, chromite, awaruite are 67.2, 16.8, 3.4, 0.6, 10.9, 0.4, and 0.4 vol.%, respectively. Crystallization sequence estimated based on the petrography is following: primary orthopyroxene =>awaruite =>ef-pigeonite =>chromite =>lf-pigeonite =>olivine =>augite (quite rare crystallized from melt) =>heazlewoodite =>pentlandite =>merrilite =>feldspar. Early formed pigeonite (blob-bearing orthopyroxene) shows a LPO of the [010] axis. Lf-pigeonite contains complex exsolution lamellae of augite. The thickest lamellae have ˜0.2 micrometer in width and 1-2 micrometer wavelength. Finest lamellae have <0.1 micrometer thick and ˜0.2 micrometer wavelength.

Discussion: Because [010] lattice preferred orientation of pyroxene in terrestrial rocks has been interpreted as settling of tabular pyroxene crystals in a stagnant magma chamber (5), ef-pigeonite could have settled in a stagnant magma chamber. Presence of $Fe^{3+}$ in chromite and high NiO concentration in olivine (0.89 wt.% on average) suggest that this meteorite crystallized under an oxidized condition. About 1100 $^oC$ equilibrium temperature was estimated by using two pyroxene geothermometry and ˜950 $^oC$ by using olivine-spinel geothermometry. These high temperatures suggest that the meteorite cooled rapidly in this range of temperature. Multiple exsolution lamellae with thickness and wavelength similar to this meteorite were observed in Zagami martian meteorite. Its cooling rate between 1100 $^oC$ to 950 $^oC$ was estimated to be ˜0.02 $^oC$/hr (6). This meteorite could be cooled as slow as Zagami did. Further studies are needed to clarify if a monotonous cooling can accomplish both high equilibrium temperatures estimated by geothermometers and sub-micrometer-size exsolution lamellae in lf-pigeonite. NWA 6704 has petrography similar to that of NWA 6693. However, there is a stark difference between these two meteorites. Blob-bearing orthopyroxene is the most abundant pyroxene in the former. On the other hand, low-Ca pigeonite is the most abundant in the latter. Therefore, it is possible that NWA 6704 is not mere a pair of NWA 6693.

References: (1) Irvine et al. (2011), (2) Warren et al. (2012), (3) Iizuka et al. (2013), (4) Ishii and Takeda (1974), (5) Jackson (1961), (6) Brearley (1991).

Keywords: NWA 6704, achondrite

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# Petrologic type from plagioclase size distribution

KAWASAKI, Takehiro[1] ; KIMURA, Makoto[1*] ; NOGUCHI, Takaaki[1]

[1]Faculty of Science, Ibaraki University

Ordinary chondrites are classified into petrologic types 3-6, reflecting thermal metamorphism. One of the criteria to classify types 5 and 6 is the size distribution of plagioclase. The size, 50 microns, has been commonly used to classify types 5 and 6. However, no any statistic study for plagioclase size has been conducted. Here we measured the size distribution, and discuss the classification of types 5 and 6. We studied 26 thin sections of types 5 and 6 from the H, L, and LL chondrite groups. Our study indicates that plagioclase of 50 microns are commonly encountered both in types 5 and 6. However, plagioclase of 80-100 microns is more abundant in type 6 than type 5. We also noticed that the size distribution of plagioclase in H6 is similar to that in type H5. The different criteria to classify H from L and LL are necessary.

Keywords: ordinary chondrite, petrologic type, plagioclase, thermal metamorphism

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# Systematic isotopic studies of REE, Sr and Ba in eucrites

SERA, Kohei[1*] ; HIDAKA, Hiroshi[1] ; YONEDA, Shigekazu[2]

[1]Department of Earth and Planetary Systems Science, Hiroshima University, [2]National Museum of Nature and Sci.

The eucrites is meteorites that probably originate from the crust of asteroid 4-Vesta. Cosmochemical and chronological information of eucrites puts important constraints of on the evolutional history of the eucrite parent body (EPB). In this study, systematic istopic isotopic studies of Sr, Ba, Ce, Nd, Sm and Gd were performed on eight eucrites for better understanding of differentiation on the EPB. $^{138}$Ce, $^{142}$Nd, and $^{143}$Nd include radiogenic components, and their isotopic variations correlate with La/Ce and Sm/Nd elemental ratios, respectively. The results were consistent with the isochron from previous studies (Makishima and Masuda, 1991; Boyet and Carlson, 2005; Andreasen and Sharma, 2007). The Rb-Sr chronometer consisting of $^{87}$Sr/$^{86}$Sr and Rb/Sr for these eucrites is now in progress. Sm and Gd isotopic compositions of the eucrites showed the isotopic shifts caused by neutron caputure reactions due to cosmic rays irradiation. These isotopic shifts correspond to the neutron fluences ranging from 0.28 to 4.05 $\times$ $10^{15}$ n cm$^{-2}$, but these are almost consistent with their cosmic-ray exposure ages, suggesting no strong evidence of initial cosmic-ray irradiation on the surface of EPB. Most previous Ba isotopic studies of meteorites focused on the variation of r- and s-process nucleosynthetic components due to additional inputs in the early solar system. $^{135}$Ba and $^{137}$Ba isotopes are sensitive to s- and r-process variations, and often have deficits and/or excesses in chemical separates in carbonaceous chondrites due to the existence of presolar grains. In case of eucrites, there are no isotopic variations of all Ba isotopes, but some samples showed the slight excess of radiogenic $^{135}$Ba probably from $^{135}$Cs decay. Systematic isotopic data obtained in this study provide a hint to understand the evolution processes of differentiated meteorites. We are now applying this technique for the analyses of cumulate eucrites and diogenites.

Keywords: eucrite, REE, chronology, isotope

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# Preliminary experiments on the formation process of lingunite in shocked meteorites

KONO, Mari[1*] ; KUBO, Tomoaki[1] ; KATO, Takumi[1] ; KONDO, Tadashi[2]

[1]Kyushu Univ., [2]Osaka Univ.

Albite-rich hollandite (lingunite) has been frequently found in shocked meteorites with other high-pressure minerals (Gillet et al., 2000; Tomioka et al., 2000). According to the laser-heated diamond anvil cell (LHDAC) experiments by Liu (1978), following the decomposition of albite ($NaAlSi_3O_8$) into jadeite ($NaAlSi_2O_6$) plus quartz ($SiO_2$) at 2-3 GPa, these phases recombine to form lingunite in the range of pressure between 21 and 24 GPa at about 1000 ℃, and then it decomposes again into calcium ferrite-type NaAlSiO4 plus stishovite at pressures above 24 GPa. Similarly, Tutti (2007) observed $NaAlSi_3O_8$ lingunite at 21-23 GPa and 2000 ℃ using LHDAC. In contrast to these LHDAC studies, high-pressure experiments using multi-anvil type (MA) apparatus revealed that the maximum solubility of $NaAlSi_3O_8$ component in hollandite structure is limited to ˜50 mol% at 14-25 GPa and 800-2400 ℃ (Yagi et al., 1994, Liu, 2006). This contradiction has not been solved yet, which makes it difficult to understand the shock conditions for the presence of lingunite in shocked meteorites. Tutti (2007) suggested that the stability of lingunite might be sensitive to temperature and could transform back when quenching rate is slow like MA experiments. However, the formation conditions of lingunite has not been well constrained even by LHDAC experiments.

To investigate the formation process of lingunite, we preliminarily carried out LHDAC experiments using a powder of natural albite as a starting material. The samples were compressed at room temperature, and then heated by the double-sided laser heating method using a Nd:YAG laser. The emission spectra were measured on both side of the heated sample, and used to estimate temperature. Heating duration at the maximum temperature was several minutes. Recovered samples were analyzed by X-ray diffraction method at BL-ARNE7 and BL-ARNE1 of photon factory, KEK. The results obtained suggest that jadeite and stishovite are present at 22 GPa and 1230 ℃. The assemblage changed into calcium ferrite-type structure and stishovite at 25 GPa and 1400 ℃. Hydrous aluminum silicate (phase egg) was also present in both samples probably due to the effect of absorbed water in the powdered stating material. We measured X-ray diffraction patterns at several points in the sample, which showed changes of the ratio of the constituent minerals due to the presence of pressure and temperature gradients, however we did not observe lingunite in any measured points. Although experimental conditions are still rather limited, our preliminary results suggest that the formation condition of lingunite is more than 1400 ℃ at these pressure ranges.

Keywords: lingunite, high pressure, LHDAC, shocked meteorite