Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PPS23-P01 Room:Convention Hall Time:May 23 18:15-19:30

The newest lunar digital elevation model (DEM) from SELENE and LRO data

Junichi Haruyama[1*], Makiko Ohtake[1], Tsuneo Matsunaga[2], Akira Iwasaki[3], Tomokatsu Morota[4], Yasuhiro Yokota[2], Yoshiaki Ishihara[5], Hiroshi Araki[6], Koji Matsumoto[6], Hirotomo Noda[6], Sho Sasaki[6]

[1]Japan Aerospace Exploration Agency / Institute of Space and Astronautical Science, [2]Center for Global Environmental Research, National Institute for Environmental Studies, [3]The Univiersity of Tokyo, Research Center for Advanced Science and Technology, [4]Graduate School of Environmental Studies, Nagoya University, [5]Geoinformatics Research Group, Information Technology Research Institute, National Institute of Adva, [6]National Astronomical Observatory, RISE Project

In this presentation, we will introduce the newest lunar digital elevation model (DEM) based on data from SELENE Terrain Camera (TC) and Multi-band Imager (MI), and LRO Lunar Orbiter Laser Altimeter (LOLA). The elevation and horizontal accuracies of this DEM are very high, perhaps higher than those of any previously released elevation mosaicked data covering all over the Moon. This DEM will be fundamental for various fields of lunar science and for planning of future lunar missions in detail.

Keywords: Moon, digital elevation model, DEM, Terrain Camera, SELENE, Kaguya

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PPS23-P02 Room:Convention Hall Time:May 23 18:15-19:30

Mare volcanism: Reinterpretation based on Kaguya Lunar Radar Sounder data

Shoko Oshigami[1*], WATANABE, Shiho[2], Yasushi Yamaguchi[2], Atsushi Yamaji[3], Takao Kobayashi[4], Atsushi Kumamoto[5], Takayuki Ono[5]

[1]National Astronomical Observatory of Japan, [2]Nagoya University, [3]Kyoto University, [4]Korean Institute of Geoscience and Mineral Resources, [5]Tohoku University

The volumes of single geological units with different ages and compositions are essential for revealing characteristics of mare volcanisms and for constraining the thermal history of the Moon. Recently, the thicknesses of mare basalt units defined by previous lithofacies maps were indirectly estimated from Clementine multispectral data. That is, the depth-diameter relationship of the craters fringed with ejecta from the underlying basaltic units placed the constraints for the estimation. The results are derived for only limited areas in Oceanus Procellarum and Mare Serenitatis.

At present, the geological structures under the lunar maria are directly investigated using sounder observations. The Lunar Radar Sounder (LRS) onboard Kaguya (SELENE) detected widespread horizontal reflectors under some nearside maria. The LRS detects, using FM-CW radar (4-6 MHz), echoes from subsurface horizons with abrupt changes in dielectric constants at the apparent depths smaller than about 1 km. Oshigami et al. [2012] concluded that the reflectors correspond to the interfaces between basalt units with different FeO contents, suggesting that buried regolith layers were responsible for the radar returns. Therefore the LRS data have great potential to determine a lava effusion volume during a series of magmatism in lunar maria and its time dependence.

Thicknesses of mare basalt units with different ages and compositions are directly estimated from the LRS data in the several regions of lunar maria. Using the technique of Ono et al. [2009], we correlate subsurface reflectors with the surface geologic units, the ages of which have been estimated by several researchers, to evaluate the volumes of the units.

The estimated thicknesses of the geologic units were of the order of 10^1-10^2 meter, and showed a positive correlation with their ages. The resolution of our estimation was limited by the range resolution of the LRS data. Previous studies indicated that the typical thicknesses of single basalt flows were about 10 m or less in most of the studied sites. These estimations suggest that the geologic units are made up of dozens of lava flows.

Weider et al. [2010] estimated the thicknesses of a number of mare basalt units in Oceanus Procellarum and Mare Serenitatis, ranging from about 80 to 600 m. For the purpose of comparison, we took the unit S15 in Serenitatis defined by Hiesinger et al. [2000]: Weider et al. concluded that the representative thickness was about 500 m although individual data derived from craters located on the unit showed a wide variation, implying large uncertainty of thier estimation. In contrast, the LRS data exhibit that the averaged thickness of the unit S15 is about 150 m.

The volumes of the geologic units estimated in this study were of the order of 10^3 km^3, and showed a clear positive correlation with their ages. Again, the resolution of our method was limited by the range resolution of the LRS data. This volume range is consistent with flow volumes derived from numerical simulations of thermal erosion model for lunar sinuous rilles formation. The large sinuous rilles are estimated to have formed by thermal erosion with sustained lava flows of volume in the range 300-1200 km^3. The volume range derived from our study also comparable to the average flow volumes of continental flood basalt units forming after the Paleozoic and calculated flow volumes of Archean komatiite flows, both possibly originated from mantle plume activities on the Earth. The estimated volumes of the geologic mare units and their age variation on each maria potentially constrain key factors for the thermal evolution of the Moon; magma buoyancy and crustal thickness, impact basin topography effects on the ascent of magma, and thermal evolution trend.

Keywords: Kaguya, Lunar Radar Sounder, Lunar maria, Subsurface structure, Volcanism

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PPS23-P03 Room:Convention Hall Time:May 23 18:15-19:30

Melting of the Fe-O-S system and reaction between olivine and iron melt at lunar core conditions

Haruka Akamatsu[1*], Eiji Ohtani[1], Akio Suzuki[1]

[1]Department of Earth and Planetary Materials Science, School of Science, Tohoku University

Despite recent insight regarding the Moon from satellite sensing and analyses of Apollo-era seismic data, there are still several unknown issues on the deep lunar interior. It is suggested that the Moon has a small iron-rich core with a radius between 220 and 450 km based on the calculated value of the mass and moments of interior (Konopliv et al., 1998), but the question about its feature is still under debate. Recent studies suggest the presence of a solid inner core and liquid outer core in the Moon (Weber et al., 2011). If we could constrain the temperature and composition of the lunar outer core, this would help us for better understanding of the lunar interior. Here, we focused on the interaction between liquid iron-alloy and solid silicate, and revealed the nature of the outer core of the Moon. The lunar mantle is characterizes by high FeO content compared to the Earth's mantle. This implies that Moon is oxidizing and oxygen can be in the lunar core. Therefore, Fe-O-S system is considered and we performed the partition experiments of oxygen between silicate and molten metal in this study.

High pressure experiments were conducted at 5 GPa from 760 C to 1400 C using 3000 ton Kawai-type multi-anvil apparatus of Tohoku University. We used powder mixtures of Fe, FeO and FeS as the metallic component of the starting material. Olivine crystals with Mg number of about 83 from Miyakejima, which is similar to the lunar mantle olivine, were used for the silicate component of the starting material. The sulfur content was 24 wt.% and the oxygen content varies 0 ~ 7 wt.% for the starting iron-alloys. Scanning electron microscope (SEM) was used for the texture observation of the recovered samples, and the electron probe micros-analyzers (EPMA) with Energy-dispersive X-ray spectroscopy (EDS) and wavelength-dispersive X-ray spectroscopy (WDS) were used to obtain the chemical compositions of recovered run products.

Some differences in reactions between the experiments made at 1000 C and at 1400 C were observed in the recovered samples. At 1000 C, the metallic sample melted partially and liquid phase had magnesiowustite crystals were observed at the boundary between the molten iron alloy and olivine. The Mg number of the olivine crystals increased with increasing the distance from the metal phase. At 1400 C, the metallic sample was totally-melted. Pyroxene and olivine crystals with reverse zoning were observed in the silicate phase, whose Mg number was higher than starting materials. The effects of oxygen content in metallic phase on silicate phase were not observed in this experimental condition. We calculated the distribution coefficient D of FeO between metal liquid and olivine crystal. Using this value, the amount of FeO in the lunar liquid outer core is 4.45 at.% at 1000 C and 1.63 at.% at 1400 C when the mantle Mg number is 80. If the amount of FeO is 4.45 at.%, the lunar outer core might have two layers because of existence of the immiscible two-liquid regions in the Fe-S-O system.

Keywords: lunar core-mantle boundary, Fe-O-S system, olivine, melting, high pressure

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PPS23-P04 Room:Convention Hall Time:May 23 18:15-19:30

Crustal materials around Mare Imbrium: result of Kaguya data integration science

Takamitsu Sugihara[1*], Makiko Ohtake[2], Junichi Haruyama[2], Tsuneo Matsunaga[3]

[1]CDEX/JAMSTEC, [2]JAXA, [3]NIES

In order to understand lithological distribution and geological structure of the lunar crust, it is important to conduct analysis of spectral images with high spatial resolution considering 3D geological structure by using high-spatial resolution topographic map. In this presentation, lithological distribution and it relationship with geological structure around Mare Imbrium will be discussed by using the Kaguya data acquired by MI, TC, KGRS and LALT. As well known, Imbrium basin is situated in Procellarum KREEP Terrane (PKT). Therefore this investigation would contributes to understand lithological structure of the PKT and influence of Imbrium basin formation on the PKT evolution. In addition to discussion on crustal materials around the PKT, implication for origin of high-Th (i.e. KREEPy) crustal materials will be discussed.

Keywords: The Moon, Lunar crust, Kaguya/SELENE, Procellarum KREEP Terrane, Magma ocean, Early evolution

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PPS23-P05 Room:Convention Hall Time:May 23 18:15-19:30

Presence of impact melts on central peaks of lunar craters and its implications

Yutaro Kuriyama[1], Makiko Ohtake[2*], Junichi Haruyama[2], Takahiro Iwata[2]

[1]The University of Tokyo & ISAS/JAXA, [2]ISAS/JAXA

Introduction: Impact melts within complex impact craters are known to be flat and smooth deposits filling the floors or wall terraces [1]. Recent studies suggest that compositionally different layers with smooth surfaces are present on the central peaks in several lunar craters, implying impact melts [2, 3]. Impact melts on the central peaks could constrain the central peak formation timescale because impact melts will flow out if peaks are uplifted too quickly. However, little evidence and few examples of impact melts on the central peaks were reported. In this study, we investigate the central peaks of the all lunar complex craters listed by [4] to check for the presence of impact melts morphologically and compositionally.

Methods: Central peak morphologies and topographies are identified using SELENE data obtained by the Terrain Camera (TC, 7.4 m/pixel) and Multiband Imager (MI, visible: 20 m/pixel and near- infrared: 60 m/pixel); MI spectral data also provide compositions of geologic units. Impact melt textures are identified by characteristic features, such as cooling cracks and flowing features (lobes or levees), using data from the Narrow Angle Camera (NAC, 0.5-1.2 m/pixel) abroad the Lunar Reconnaissance Orbiter (LRO) in addition to SELENE data.

Results: At least 13 of the analyzed central peaks have distinctive impact melt morphologies on their slopes. Seventy craters (including the above mentioned 13 craters) have spectrally unique geologic units on their gentler slopes with smooth surfaces exhibiting low albedo and weak absorption depth similar to their floor melts. The 70 craters vary in setting, diameter, and formation age, while almost all the 13 distinctive melt morphologies are observed in the craters formed in Copernican period [4], which is the latest selenogical period.

Discussion and Conclusions: Our observation that impact melts are found on the central peaks of more than half of the Copernican period craters implies that many central peaks could have impact melts. My analysis suggests that the unique geological units on the 70 central peaks are possibly impact melt origin, and melt morphologies on the older central peaks are probably obscured by erosion, which implies it is common that impact melts did not flow out completely from the central peaks when the peaks were uplifted. This suggests that impact melts already had relatively high viscosity but were not completely solidified when central peaks were uplifted.

References: [1] H. J. Melosh (1989) Impact Cra-tering -A Geologic Process. Oxford, New York, New York, USA. 245 pp. [2] M. Ohtake et al. (2009) Nature, 461, 236.241. [3] G. R. Osinski (2011) Earth Planet. Sci. Lett., 310, 167-181. [4] S. Tompkins and C. M. Pieters (1999) Meteorit. Planet. Sci., 34, 25.41

Keywords: central peak, moon, SELENE, impact crater, impact melt

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PPS23-P06 Room:Convention Hall Time:May 23 18:15-19:30

Estimating the origin and thickness of high-thorium-content rock units on the lunar surface

Kiyotaka Ito[1], Makiko Ohtake[2*], Junichi Haruyama[2], Takahiro Iwata[2]

[1]The University of Tokyo, [2]JAXA

The abundance and distribution of thorium, an incompatible element, within a planetary body are very important for understanding the thermal history of a terrestrial planet because it correlates to the heat-source elemental abundance of these planets. Gamma-ray remote-sensing data depicts the global distribution of thorium of the lunar surface, in which thorium concentrates in the western hemisphere of the lunar near side around the mare region. Within this high thorium area are several hot spots, which have significantly higher thorium content. Lunar rocks containing abundant incompatible elements are called KREEP-rich rocks based on the Apollo sample analyses. KREEP should be formed in the boundary area between the lower crust and the upper mantle. However, the KREEP-rich rock is exposed on the lunar surface. Two processes were proposed as the mechanism for transporting KREEP-rich rocks from under the crust to the surface. One is an igneous process, in which KREEP-rich basalts erupt from magma generated in a deep area at the bottom of the crust. The other mechanism is the ejecta origin of Imbrium basin, in which a basin-formation event excavated the lower crust including KREEP-rich rocks and spread it as ejecta on the surface. The thorium hot spots can be considered to have been formed by either mechanism. However, because of a low spatial resolution of gamma-ray observation from orbit, we cannot identify the corresponding rock types of the thorium hot spots. Therefore, the actual distribution of the high thorium unit and its thorium abundance has not been well understood.

In this study, we used high-resolution visible to near-infrared band images obtained by Kaguya (SELENE) and combined them with a simulated thorium abundance based on Lunar Prospector gamma-ray data to estimate the origin of the thorium-rich rocks and their thorium concentrations. We selected two hot spots (Aristillus and Copernicus) to analyze as candidates of the two KREEP origins. Aristillus is a crater within the Imbrium basin, while Copernicus is located outside of the Imbrium basin.

Our results indicate that KREEP-rich rocks around Aristillus contain high calcium pyroxene, and its thorium abundance is estimated to 35 ppm, while there appears to be no thorium inside the crater. In contrast, KREEP-rich rocks around Copernicus contain low-calcium pyroxene with 12 ppm thorium content. By combining the results with their geologic contexts, KREEP rick rocks in Aristillus (Copernicus) are estimated to originate from KREEP basalts (Imbrium ejecta). The KREEP layer around Aristillus is estimated to be 1.6 km thick, and that around Copernicus is estimated to be 9 km thick. These results suggest that the thorium concentration within the crust is not uniform as assumed in a previous model but it forms a layer. It also clearly demonstrates that the previous model assuming constant thorium content within the crust from surface to the bottom (60 km deep) needs modification. Our estimation based on our new thorium abundance model for the Procellarum KREEP terrane derives much lower thorium abundance (50% less) than previously estimated.

Keywords: moon, thorium, thermal history

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PPS23-P07 Room:Convention Hall Time:May 23 18:15-19:30

The formation and reactivation of a mare ridges in northern Imbrium

Yuko Dake[1*], Atsushi Yamaji[1], Katsushi Sato[1], Tomokatsu Morota[2], Junichi Haruyama[3], Makiko Ohtake[3], Tsuneo Matsunaga[4]

[1]Kyoto University, [2]Graduate School of Environmental Studies, Nagoya University, [3]Japan Aerospace Exploration Agency / Institute of Space and Astronautical Science, [4]Center for Environmental Measurement and Analysis, National Institute for Environmental Studies

Mare ridges are the manifestations of horizontal compressions in the shallow part of the lunar crust. They have been interpreted as the folds that determined the basaltic lava layers in mare basins. Since the distribution of the ridges is usually concentric with respect to basin centers, the compressional stress is thought to be originated from the flexure of lithosphere caused by the loading of mare basalts, which is called mascon tectonics. Possible mantle viscosity allowed such deformations to have had delay time of the order of 0.1 Gyr from the deposition of the basalt, which means the deformation was almost syndepositional. However, recent investigations on the underground structures showed that there is no lateral change of thickness of basalt lava around ridges, and this fact supports the post-depositional formation of ridges. On the lunar surface, the majority of mare basalts deposited before 3.0 Ga. Thus, the most of the ridge formation should have occurred before 3.0 Ga. The timing of the formation will be the clue to distinguish their origin, among global cooling, orbital evolution of the Earth?Moon system and mascon tectonics. This study found a crosscutting relationship between a ridge and a basalt unit, then constrained the formation age of the ridge using depositional ages of basalt lava units derived from the crater-size frequency distribution (CSFD).

By means of optical data taken by the cameras onboard SELENE (Kaguya), an ENE-WSW trending mare ridge that dammed up a relatively high-Ti basaltic unit was found near Sinus Iridum, northern Imbrium. The ridge is 300–400 m high, ˜30 km wide and ˜150 km long. Relatively high-Ti unit is dammed up by the ridge and relatively low-Ti unit made up the ridge. It was also found that the lowermost part of the ridge is partially covered by high-Ti unit, that is, a part of the ridge was uplifted after the deposition of the high-Ti basalt. In addition, there is a smaller ridge of ˜50 m in the younger unit. The smaller ridge runs roughly parallel to the ridge mentioned above. The reactivation and the formation of the small ridge showed that a compressional deformation occurred in the area after the deposition of high-Ti basalt. This study determined the depositional ages of high-Ti unit and low-Ti unit by performing CSFD measurements. The estimated ages were 3.0 Ga and 2.1 Ga for low-Ti unit and for high-Ti unit, respectively. The cross-cutting relationship showed that the major formation age of the ridge was between 3.0 to 2.1 Ga. Furthermore, it was revealed that the reactivation and the smaller ridge formation occurred after ˜2.1 Ga. Since most of the mare basalts were deposited before 3.0 Ga in the Imbrium basin and the ridge is a part of concentric ridges of the basin, the formation of the ridge was possibly induced by the latest stage of the mascon loading. However, the reactivation of the large ridge and the formation of the small ridge were too young for the mascon, requiring some mechanisms other than the loading. Global cooling and the increasing Earth-Moon distance are possible explanation.

Keywords: mare ridge, chronology, formation age

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PPS23-P08 Room:Convention Hall Time:May 23 18:15-19:30

Assessment of Hemispherical Spatial Distribution of Craters on the Lunar Farside.

Riho Ito[1*], Tatsuo Kinoshita[1], Chikatoshi Honda[1], Naru Hirata[1], Tomokatsu Morota[2]

[1]University of Aizu, [2]University of Nagoya

The impact craters on planetary surface show random spatial distribution. However, lunar surface expect to have a bias of spatial distribution of crater because the Moon have same rotation and revolution periods.

The previous research showed that rayed crater density at the apex (0 N, 270 E) is highest than antapex (0 N, 90 E). I compared crater size-frequency distribution of apex and antapex side about craters of over 20 km in diameter. In the result, the crater size-frequency distribution of the antapex side was higher than the apex side.

Purpose of this research is to develop an algorithm to assess spatial distribution of craters on lunar farside by using clustering analysis for finding where bias of craters is. In this algorithm, I apply the nearest single-linkage clustering (S-LINK) to simulated and actual craters, and assess whether the crater is random or not by comparing both of results. As a result, 2870 of 3112 craters were decided to non-random (1403 craters are at the apex side, and 1467 craters are at the anapex side). I investigated the crater frequency variation with longitude and latitude. The high frequency of non-random craters was found at north high latitude region, apex side (210 to 270 E) and antapex side (90 to 150 E).

Keywords: Crater, Spatial distribution, Clustering analysis, apex

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PPS23-P10 Room:Convention Hall Time:May 23 18:15-19:30

Present Status of the next lunar landing mission SELENE-2 (3)

Satoshi Tanaka[1*], Takefumi Mitani[1], Hisashi Otake[1], Kazunori Ogawa[1], Naoki Kobayashi[1], Tatsuaki Hashimoto[1], Takeshi Hoshino[1], Masatsugu Otuki[1], Sachiko Wakabayashi[1], Jun Kimura[2]

[1]Japan Aerospace Exploration Agency, [2]Center for Planetary Science Department of Cosmosciences, Hokkaido University

SELENE-2 project has been started from 2007 as the first Japanese lunar lander. The main prior object of the SELENE-2 mission is to develop safe and precise landing system on middle to large planets and satellites such as the Moon and Mars for a future lunar and planetary exploration. Another key technologies under investigation are surface mobility by a rover, and long night survival module without using nuclear power. In addition, some instruments for lunar science and future utilization have been so far investigated.

The Strategic Headquarters for Space Policy of Japanese government established ”Basic Plan for Space Policy” in June, 2009. Following the plan, a concrete strategy of Japanese lunar exploration had been discussed in ”Study group for lunar exploration” of Japanese government which was organized from August, 2009 to July, 2010. The final report of the group indicates that a spacecraft should land on lunar surface in around 2015 to promote lunar exploration using advanced robot technology in 2020. Despite of this result, the SELENE-2 is delayed and still remains as the Phase-A study. Presently, the earliest launch date is 2018 when we successfully proceed to Phase-B within the fiscal year 2013.

One of our meager but important progresses are that technological development of candidate instruments, especially, we have developed seismometry system and camera system, both of which were considered to be main scientific instruments for geophysical and geological instruments. As for the seismometry system, we have almost successfully performed interface tests which were done by international collaboration. Development of a sensor of the visible to near infrared camera system, on the other hand, also conducted good performance under the suitable temperature condition on board the rover.

We are preparing for the upcoming review board to proceed to phase-B study. In order to achieve it, we are under investigation to make high reliable system, and realistic scenario of the mission profile assuming some appropriate landing sites which have been selected among the Japanese lunar scientists. Further technical development is also to be aggressively continued for reducing risks.

Keywords: Moon, Lunar exploration, SELENE-2

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PPS23-P11 Room:Convention Hall Time:May 23 18:15-19:30

Recent status of SELENE-2/VLBI instrument

Fuyuhiko Kikuchi[1], Koji Matsumoto[1*]

[1]RISE Project, National Astronomical Observatory of Japan

We proposed a VLBI (very long baseline interferometry) radio source mission for the Moon lander SELENE-2. The purpose of our mission is to improve the lunar gravity field and to estimate the lunar interior structure. Differential VLBI observations between an orbiter and a lander are carried out to determine the position of the orbiter and the lander in addition to the conventional 2-way Doppler observation (Fig.1). VLBI measures a difference in an arrival time of a signal transmitted from a radio source to two ground stations. This measurement gives plane-of-sky position information of the radio source in contrast to 2-way Doppler measurement that gives line-of-sight position information. The combination of VLBI with Doppler is effective for precise position determination of the spacecraft.

This presentation shows the recent status of the VLBI radio source mission of SELENE-2.

1. A simulation study of the lunar gravity field estimation is carried out. The result shows that a potential Love number k2 accuracy better than 1 % can be achieved by 3 months of the VLBI mission duration provided that arc length is 14 days and that historical tracking data including SELENE are combined with.
2. The sensitivity of the geophysical parameters, in particular that of k2, the moment inertia of the Moon, and the seismic travel time, for the lunar deep interior structure is evaluated. A preliminary result shows that a density and a radius of the lunar core can be estimated within the error of 10 %.
3. We have conceptual design for an antenna that will be used on the lunar surface. A simulation evaluates the electric characters of the antenna, which are the gain, the beam pattern, and its temperature characteristics.
4. In order to decrease the power consumption of the VLBI radio source, the observation method and the manner of the operation are reconsidered.

Keywords: selene-2, vlbi, moon, internal structure

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PPS23-P12 Room:Convention Hall Time:May 23 18:15-19:30

An implementation of a visualization system for large scale moonquake data considering waveform similarity

Yasumichi Goto[1*], Ryuhei Yamada[2], Yukio Yamamoto[3], YOKOYAMA,Shohei[4], ISHIKAWA,Hiroshi[4]

[1]Graduate School of Informatics, Shizuoka University, [2]National Astronomical Observatory of Japan, RISE project, [3]The Institute of Space and Astronautical Science, [4]Department of Computer Science, Faculty of Informatics, Shizuoka University

Large-scale seismic data were obtained from seismometers located on the Moon by the NASA Apollo missions from 1969 to 1977. According to previous analysis of the lunar seismic data (e.g., Lammlein, 1977), we found that deep moonquakes occur periodically from identical sources at a depth of about 700 to 1200km. The deep moonquakes occurred from identical sources have high similarities among each waveform (e.g., Nakamura, 2003). This similarity is important to classify the sources and investigate the generation mechanism of moonquakes. From the reason, classification of moonquakes has been processed, and much of lunar seismic data observed by long-period seismometers are labeled in term of type of moonquakes and location of sources (Nakamura et al., 2008).

However, classification of enormous moonquake data is usually difficult even if we use the computers, because we don't have any true references and the lunar seismic data are contaminated by large noises. We may not necessarily obtain useful results using classical cross-correlation method to all lunar seismic data.

We, therefore, develop the web system for visualizing moonquakes considering waveform similarity to progress study of moonquake classification. Our system maps moonquakes data to two dimensional output space using Self-Organizing Map (SOM). We use Hadoop in the back-end system to apply visualization methods to enormous moonquakes data. We will be able to indicate the results of classification in terms of various physical conditions, because SOM can automatically classify the waveforms based on our designed characteristics. Through development of this Web interface system, it will be expected that many researchers can utilize our indicated results and moonquake data to their analysis. In this presentation, we will show results of the classification of moonquakes by the SOM and current situation of our development.

Keywords: Moonquake, Visualization, Self-Organizing Map, Hadoop

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PPS23-P13 Room:Convention Hall Time:May 23 18:15-19:30

Develpoment of the retro-reflector on the moon for the future lunar laser ranging

Hiroshi Araki[1*], Kashima Shingo[1], Hirotomo Noda[1], Hiroo Kunimori[2], Mashiko Hiutomi[3], Toshimichi Otsubo[4], Utsunomiya Shin[5], Matsumoto Yoshiaki[6]

[1]National Astronomical Observatory of Japan, [2]National Institute of Information and Communications Technology, [3]Iwate Univercity, [4]Hitotsubashi Univercity, [5]Institute of Space and Astronautical Science, [6]PLANET INC.

Lunar Laser Ranging (LLR) data are important for the investigations of the lunar rotation, tide, and lunar deep interior structure. The range accuracy of LLR has been less than 2 cm for the last 20 years due to the progress of laser transmit/receive system on the ground stations and the atmospheric signal delay model, however, one order or more accurate ranging than 2cm is needed for better understanding of the lunar deep interior. Murphy et al. [1] showed that the main source of range error comes from the fact that the existing retro-reflectors on the lunar surface are array-type ones which consist of arrays of small corner cube prisms (CCP).

To overcome this problem, large single aperture retro-reflectors are necessary with very small offset angles (dihedral angle offset; DAO) between reflecting surfaces, which must be employed for the management of the 'velocity aberration problem' [2,3]. We are developing 'single aperture and hollow' retro-reflector (corner cube mirror; CCM) to be aboard future lunar landing missions. The aperture of CCM is 20cm because the reflection efficiency of that size is found to be higher than that of Apollo 11 array CCP, and 'ultra low expansion glass-ceramic (CCZ-EX; OHARA Inc.)' or 'single crystal Si' are selected for candidate material of CCM in terms of small |CTE|/K (Thermal expansion coefficient over thermal diffusivity). The optical performance of CCM deformed by lunar gravity or solar illumination in the gimbal model will be presented for some cases. We are now trying to fabricate CCM test model made from CCZ-EX using the optical contacting method that is applicable to single crystal Si, too.

References: [1] Murphy T. et al. (2008) PAPS, 120, 20-37. [2] Otsubo T. et al. (2010) Adv. Space Res., 45, 733-740. [3] Otsubo T. et al. (2011) Earth Planet Space, 63, e13-e16.

Keywords: Lunar Laser Ranging, Retroreflector, Single, Hollow, CCZ-EX, Single crystal silicon

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PPS23-P14 Room:Convention Hall Time:May 23 18:15-19:30

Developing a test model of Laser-Induced Breakdown Spectroscopy for mounting lunar and planetary rovers

Yu Okumura[1*], Shingo Kameda[1], Ko Ishibashi[2], Koji Wada[2], Noriyuki Namiki[2]

[1]Rikkyo University, [2]Chiba Institute of Technology

JAXA is currently planning the moon lander SELENE-2 project, a follow-on mission of SELENE. This project involves the dispatch of a lunar rover to investigate the lunar surface and rocks. JAXA has nominated Laser-Induced Breakdown Spectroscopy (LIBS) as instrument for mounting rovers. The LIBS determines the elemental compositions right on-the-spot. The Curiosity rover, part of NASA's Mars Science Laboratory mission, used LIBS to obtain the spectra of rocks present on the Mars surface.

The LIBS instrument uses a powerful laser pulse and induced plasma. The plasma emits energy in the form of photons. The analysis of the plasma via spectroscopy enables the determination of the elemental composition.

Test model LIBS uses a lens to obtain the breakdown threshold of the energy density and can automatically set the target at a focal point within 1.0-1.5 m.

We developed a software for the test model LIBS. We also attended the field-roving test of one of the prototype lunar and planetary exploration rovers, Micro-6, at Mt. Mihara on Izu ?shima in the Izu Islands in Tokyo from October 28 to November 3, 2012. We conducted a successful rock-surface breakdown using LIBS. Furthermore, we carried out this operation via radio communication. However, we could not always set the focal point target via auto-focus because the charge-coupled device (CCD) camera causes electronic saturation, probably the result of the difference in reflection of the target rock. To address this issue, we developed a new program that automatically adjusts the exposure time of the CCD camera and provides a new method for auto-focusing.

Keywords: elemental compositions, LIBS, Moon, Mars

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PPS23-P15 Room:Convention Hall Time:May 23 18:15-19:30

Performance of a visible-InGaAs sensor onboard a lunar exploration camera

Chikatoshi Honda[1*], Daisuke Torii[2], Makiko Ohtake[3], Tatsuo Kinoshita[1], Kazuto Saiki[2], Tomokatsu Morota[4], Hisashi Ootake[3]

[1]University of Aizu, [2]Osaka University, [3]Japan Aerospace and Exploration Agency, [4]Nagoya University

Information of the lunar highland could help us to know the solidification of the lunar magma ocean and to estimate the internal structure of the Moon. We are now planning to develop a visible-SWIR macro camera with rock abrasion tool (RAT) which is required to establish a light-weighting for setting on a head of rover's arm. The purpose of this camera is to observe the texture of polished rock surface (grain size, shape, species, and crystal configuration) to investigate the geologic history of the rock. The target crystal grain size is about 200 um in average diameter. We thus need a 500 x 500 pixel sensor to achieve 20 um/pixel spatial resolution with fields of view exceeding 100 mmphi. Spectra in the 0.8 ? 1.7 um region is important to analyze major mineral species found on the Moon. So, these requirements are achieved by a visible-InGaAs sensor which has sensitivity from visible to infrared wavelength. It is important to know the performance for using space exploration, especially, an environment at the lunar surface. We'll report the details of the examinations about a dark current test of a visible-InGaAs sensor.

Keywords: visible-InGaAs sensor, dark current

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PPS23-P16 Room:Convention Hall Time:May 23 18:15-19:30

High-resolution spectroscopic observation of sodium atom emitted from the lunar surface using a Haleakala 40cm telescope

Taishi Suzuki[1*], Takeshi Sakanoi[1], Masato Kagitani[1], Shoichi Okano[1]

[1]Planetary Plasma and Atmospheric Research Center, Graduate School of Science, Tohoku University

The Moon has completely collision-free atmosphere with its surface pressure of about 10^{-17} times compared to that of the Earth. Previous studies showed that the lunar exosphere is consisted of He, Ar, Na, K, H, O. Among these constituents, Na anc K have large resonant scattering cross sections, making ground-based observation of these atoms in the lunar exosphere relatively easy and a variety of observations has been made in the past.

Locality of Lunar sodium exosphere was suggested by observation of Lunar sodium atmospheric emission using Lunar circular orbit satellite Kaguya [Kagitani et al., 2010]. Lunar surface has Mare and Highland, those rock and telluric accidents are different. It is expected that these differences make locality of Lunar sodium exosphere. And, there are 4 source process mechanisms of Lunar exosphere, Photo-stimulated desorption (PSD), solar wind ion sputtering, vaporization by micrometeoroid impacts and thermal desorption, but contribution to quantitative source amounts and variety about time and space of each processes are not clear. From the above, purpose of our research is investigation into locality and time variance of Lunar sodium exosphere.

We observed at summit of Mt. Haleakala, Maui island, Hawaii, America, in the period of 18-25, 2011 and August 8-9, 2012 using our 40cm Schmidt-Cassegrain telescope and a high dispersion Echelle spectrograph. When we observed, we put on slit that length is 500 arcsec. at right angles to Lunar rim, made clear about distribution of sodium emission from surface to a height of 300km. On July 2011, we observed on Mare Orientale located at Long. 90 deg. W Lat. 20 deg. S, and Highland that located on a point of symmetry, Long. 90 deg. W Lat. 20 deg. N.. On August 2012, we focused on Oceanus Procellarum and expected to change amounts of Lunar sodium atmospheric emission from south to north, we observed on 5 points, Long. 90 W Lat. 50 deg. N, 20 deg. N, 0 deg., 20 deg. S, and 50 deg. S. From these observation, it was revealed that height distribution of sodium emission have thermal component (about 100K) and suprathermal component (about 1000K) in many cases.

About result of observation on July 2011, we investigated time variation of absolute emission intensity of suprathermal component, and saw brightening on July 19. At same time, number density of solar wind proton increased, so we thought that this brightening is result of contribution to PSD from gardening effect by solar wind ion sputtering. And, because this brightening is seen more at south hemisphere especially, it is suggested that gardening effect become intense especially at south hemisphere.

From result of observation on August 2012, about absolute emission intensity of both of suprathermal component and thermal component, that of south hemisphere is tend to be more than that of north hemisphere. About suprathermal component, from same discussion of observation of July 2011, we can interpret that gardening effect become more intense at south hemisphere. On the other hand, about thermal component, we take account of contribution of rebound particles of suprathermal component in source process, it is expected that encouragement of gardening effect to PSD of suprathermal component is reflected to thermal component. From this result, it is assumed that thermal component also has asymmetry of north and south.

South hemisphere has more area of highland than north hemisphere. So increase of absolute emission intensity at south hemisphere indicates that release rate of sodium at highland is higher than that of mare. Or, highland is more ups and downs and have large surface area per a unit surface, so it is thought that gardening effect with incidence of solar wind proton become more intense.

Kagitani et al., 2010, Planetary and Space Science, 58, 1660-1664, Variation in lunar sodium exosphere measured from lunar orbiter SELENE (Kaguya)

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PPS23-P17 Room:Convention Hall Time:May 23 18:15-19:30

Subsurface magnetization source of Reiner Gamma and Rima Sirsalis magnetic anomalies on the Moon

takashi yokoyama[1*], Futoshi Takahashi[1], Hideo Tsunakawa[1]

[1]Department of Earth and Planetary Sciences, Tokyo Institute of Technology

Since the Apollo missions, observations by magnetometer and electron reflectometer disclose presence of magnetic anomalies on the Moon. However, the origin of the lunar magnetic anomaly is still controversial. To infer the origin, it is essentially important to have information on magnetization of magnetic anomaly source. In this study, we have modeled lunar magnetic anomalies in two regions to gain insights into their formation process. Here the Reiner Gamma and Rima Sirsalis anomalies are focused. We use Lunar Prospector magnetometer data obtained during the low-altitude observation period. As a first step, a simple dipole source is assumed for modeling. Then, based on the results from the dipole model, the magnetic anomaly is modeled by a uniformly magnetized vertical prism. As a result of forward modeling approach, five magnetic anomalies within the two regions are suitably modeled. As for the Reiner Gamma anomaly it is found that locations and shapes of the prisms correspond well with the surface feature such as high albedo swirl morphology. Such correspondence suggests association of a magnetic anomaly source with high albedo feature. For the Rima Sirsalis anomaly, two slender sources are located at the depth of 8 km, which extend along the Rima Sirsalis rille. According to the result, the magnetic anomaly source may be related with the rille below the surface. The present study demonstrates that adopting a finite-size magnetized body such as prism is more beneficial rather than a dipole to discuss correlation of magnetic anomaly with other structures at the surface and below.

Keywords: moon, magnetic anomaly, prism source, swirl, rille