Japan Geoscience Union Meeting 2012
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Spatial distribution and source region of Martian CH4 searched by the observation with SUBARU/IRCS

AOKI, Shohei[1*], NAKAGAWA, Hiromu[1], KASABA, Yasumasa[1], Anna Geminale[2], Marco Giuranna[2], Giuseppe Sindoni[2], Davide Grassi[2], SAGAWA, Hideo[3], MENDROK, Jana[4], KASAI, YASUKO[3]

[1]Dep. Geophysics Graduate School of Science Tohoku University, [2]IFSI, INAF, Italy, [3]National Institute of Information and Communications Technology, [4]Department of Computer Science, Electrical and Space Engineering Division of Space Technology

We observed Mars for the search of CH4 in January and April 2012 using SUBARU/IRCS. It aims to clarify the spatial distributions and the production region of Martian CH4, which has only reported by the limited groups. The analysis is now on going. This paper will show the preliminary results.

In 2004, a small amount of CH4 was discovered in the Martian atmosphere (e.g., Formisano et al., 2004). This discovery is remarkable because its sources are potentially geological or biological activities (Atreya et al., 2007). However, it is still an open question what the CH4 producing mechanism is and where the source of CH4 is. The identification of the source of CH4 is important not only for scientific progress but also for future life exploring missions on Mars. That is because recently a CH4 oxidizing microorganism was discovered on the Earth (Beal et al., 2009), and such kind of life is potentially alive around the source of CH4 on Mars.

The Martian CH4 was detected by CSHELL (R=40,000) on NASA Infrared Telescope Facility (IRTF) (Mumma et al., 2009) and by Planetary Fourier Spectrometer (PFS) onboard Mars Express (MEX) (Geminale et al., 2011). However, the obtained spatial and temporal variations disagreed. At the moment, there are no other observational results. Zahnle et al. (2011) showed that the previous ground-based observations by IRTF/CSHELL had large uncertainties. It suggested that the contaminations from telluric 13CH4 lines would be fatal, which were 10-50 times stronger than the Martian CH4 lines. In order to characterize and eliminate such contaminations, we performed simultaneous observations of six independent Martian CH4 lines (3038, 3028, 3010, 3000, 2990 and 2979 cm-1) with and without contamination from telluric 13CH4 lines using IRCS echelle spectrograph (R=40,000) for SUBARU telescope. We attempted to investigate the spatial distribution and possible source areas of CH4, i.e. (1) the areas, where the extend plumes of CH4 were detected by IRTF/CSHELL and MEX/PFS, and (2) the mud volcanism areas. On Earth, mud volcanism vents major quantities of CH4 (10 x 106 tons/year), which have been estimated to be about 25 % of the CH4 released to the atmosphere each year by geological sources (Etiope and Klusman, 2002). On Mars, the potential for mud volcanism in the Northern Plains of Mars has been recognized. In particular, the mounds in Acidalia Planitia and the Utopia/Isidis pitted cones (UIPC) are suggested as mud volcanism areas (Dorothy and Carlton, 2010; McFowan, 2011). It is remarkable that the areas, where the extend plumes of CH4 were detected by IRTF/CSHELL, are located on the same outer ring of the Isidis basin that intersects UIPC, which suggests that the mud volcanism area might be the source of CH4. On 4-5 January 2012 using SUBARU/IRCS, we observed the UIPC and the areas observed before as being CH4 rich. The other mud volcanism area will be observed on 12, April 2012. The latter will be simultaneous observations with MEX/PFS in order to validate the results.

In addition to the observations with SUBARU/IRCS, we also investigate the vertical profile of CH4 using MEX/PFS. PFS is currently the best space-born instrument for the detection of CH4 although due to the limitation of its spectral resolution the observed absorption depth of CH4 is reduced by a factor of 100 compared to the high resolution one. The vertical profile of CH4 is of interest because Formisano et al (2009) suggested that the maximum abundance of CH4 was not observed close to the soil, but in the middle of the atmosphere at 25-35 km. In order to derive the quantitative profile, we adapt the SARTre model, a radiative transfer code with multiple scattering for limb geometry observations developed for the terrestrial atmosphere (Mendrok, 2006), to be applied for the Martian atmosphere together with PFS team. In the presentation, the current status of the model development will also be reported.

Keywords: Mars, life, CH4, mud volcanism, infrared spectroscopy, SUBARU telescope

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SIMPLER: the Simultaneous Imaging Polarimeter onboard the MELOS Orbiter

NAKAKUSHI, Takashi[1*], OGOHARA, Kazunori[2], IMAMURA, Takeshi[2], SATOH, Takehiko[2]

[1]Faculty of Tourism, Wakayama University, [2]Japan Aerospace Exploration Agency, Institute of Space and Astronautical Science

Polarimetry is a powerful method to reveal properties of planetary aerosols. Polarimetric effects are produced by both the surface and atmosphere on Mars. Polarization dependences on phase angle and wavelength enable us to distinguish aerosols (i.e., water-ice clouds and dust clouds) and the surface.

Mars polarimetry observations were few in the records; imaging-polarimetry observations were fewer, and multi-color polarimetry were much fewer. One of the reason is the difficulty. Usually, polarimetric imaging needs rotating of the polarizer; in the meanwhile, imaging condition changes (e.g, seeing, Mars rotation, and so on), which degrades accuracy.

Polarimetric phase functions of Mars mainly have been investigated with Earth-based telescopes, but observations from the Earth limit the phase angle within the range of 0-45 degrees and cannot obtain a phase curve of a single cloud.

A new imaging-polarimetry instrument, called SIMPLER (SIMultaneous IMaging PoLarimetER), is being designed for a to-be-proposed Mars exploration mission of Japan, MELOS. SIMPLER is a multi-eye camera, like the Venus Monitoring Camera (VMC) on board ESA's Venus Express, so that it can take I+Q, I-Q, I+U and I-U images simultaneously, eliminating uncertainties of ordinary "sequential" data acquisition methods. Another advantage is that the solar phase angle of the planet changes as the spacecraft orbits around the planet. Therefore, polarization phase curves, covering a wide range of phase angles, can be obtained every orbit so that the polarization maps may be interpreted with less ambiguity. This should enable us to distinguish different types of aerosols and to study their spatial and temporal variabilities. In this paper we present the outline of the SIMPLER and related research plans.

Keywords: Mars, polarimetry, aerosol, dust

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Development of superconducting detectors for mm/THz band heterodyne spectroscopy of planetary atmospheres

MAEZAWA, Hiroyuki[1*]

[1]Department of Physical Science, Osaka Prefecture Univ.

We are developing quantum noise limited detectors employing SIS(superconductor-insulator-superconductor) junctions and superconducting HEBs (hot electron bolometers). These detectors function as heterodyne receivers for millimeter-wave and terahertz frequency bands, which allow us to research planetary middle atmospheres with high frequency resolution (f/df = ~10^{6-7}). Retrieval analysis of the observed spectral lines provide us important information about atmospheric dynamics, vertical distribution of minor constituents and temperature, and so on.

We have promoted SPART (Solar Planetary Atmosphere Research Telescope) project developing a 10-m single dish ground-based telescope equipped with a low noise 100 GHz band SIS receiver. In 2011 we have just started test regular monitoring toward the middle atmosphere of Mars, Venus, and gas-giant planets to study the influence of solar activities on their atmospheric environment (Moribe et al. in this conference). For this mission we are additionally designing highly sensitive 230 GHz band SIS detectors with high linearity performance by newly optimizing novel tuning circuits and array junctions. By spectroscopy for different transition lines at these two frequency bands (e.g. CO J=1-0, 2-1), we will be able to derive the physical parameters with retrieval analysis more accurately, and perform line survey observation efficiently.

Broadband 1-2 THz band HEB mixer detectors have been also developed for the 30cm-telescope (Tsukuba Univ.), NANTEN2 (The Univ. of Tsukuba), and BSMILES(balloon-borne sperconducting submillimeter-wave limb-emission sounder (NICT)) so on, which allow us to observe various lines of key atmospheric minor constituents including fine structure lines of atoms and ions and rotation-vibration lines of such as OH radical with high frequency resolution. Improve the sensitivity and bandwidth of the detector we are currently optimizing the length and thickness of NbTiN nano-bridge by using a scanning electron beam lithography system and an original multiple sputtring/deposition system, and performing test heterodyne measurements.

we will present these current status.

Keywords: Planetary atmosphere, Heterodyne spectroscopy, Millimeter-wave/THz band, Superconducting device, Ground based radio-telescope

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Introduction to the submillimeter receiver system for the atmospheric emission sounder FIRE/MELOS

KIKUCHI, Kenichi[1*], SAGAWA, Hideo[1], KURODA, Takeshi[2], KASAI, YASUKO[1], OCHIAI, Satoshi[1], Toshiyuki Nishibori[3], Takeshi Manabe[4], Paul Hartogh[5], Joachim Urban[6], Donal Murtagh[6]

[1]NICT, [2]Tohoku University, [3]JAXA, [4]Osaka Prefecture University, [5]MPS/Germany, [6]Chalmers Univ./Sweden

The Far-Infrared Experiment, FIRE, is a submillimeter-wave atmospheric emission sounder proposed as an onboard scientific instrument of the future Japanese Mars exploration orbiter MELOS. The FIRE submillimeter receiver will consist of 500-GHz, 600-GHz, and possibly lower frequency band receivers, to observe the submillimeter emission from the Martian atmospheric minor species and surface.

FIRE will provide unique and powerful data set in the synergy between FIRE and other instruments of MELOS. The high sensitive submillimeter receiver enables measurement without solar light, will allow us to study the local time dependency of Martian parameters. Moreover, since the submillimeter wave is more transmissive than UV, optical, and IR against the typical dust particles, FIRE will bring us information of field, such as temperature, inside of the dust.

One of the challenges to develop the FIRE instruments is to realize a lightweight and low-power consumption to meet with the limited resources of planetary exploration spacecraft. As part of this effort, we are going to develop a lightweight antenna optics made of carbon fiber instead of the conventional aluminum. This paper briefly introduces the FIRE receiver system and strategy of observation.

Keywords: Mars, MELOS, FIRE, submillimeter-wave sounder, receiver

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Sensitivity study for the submillimeter-wave atmospheric emission sounder FIRE onboard a Martian orbiter

SAGAWA, Hideo[1*], KURODA, Takeshi[2], KASAI, YASUKO[1], KIKUCHI, Kenichi[1], OCHIAI, Satoshi[1], Toshiyuki Nishibori[4], Takeshi Manabe[3], Paul Hartogh[5], Joachim Urban[6], Donal Murtagh[6]

[1]NICT, [2]Tohoku University, [3]Osaka Prefecture University, [4]JAXA, [5]MPS/Germany, [6]Chalmers Univ./Sweden

The Far-Infrared Experiment, FIRE, is a submillimeter-wave atmospheric emission sounder proposed as an onboard scientific instrument of the future Japanese Mars exploration orbiter MELOS. The scientific goal of FIRE/MELOS is to understand the dust suspended meteorology of Mars. FIRE will observe key meteorological parameters without being hampered by the Martian dust opacity; such as atmospheric temperature profiles, atmospheric compositions and their isotopes, and wind velocity profiles. FIRE will also provide the local time dependency of these parameters.

This paper discusses the expected sensitivity of FIRE/MELOS under the basic instrumental design. The disk-mapping observation mode will be used to obtain the horizontal distribution of temperature and water vapor (H_2O) profiles. The temperature and H_2O abundance at the first scale height of the Martian atmosphere will be measured with a precision better than 1 K and 10%, respectively. The deuterated water (HDO) will be also detected with a zonally averaged data set. The limb-scanning observation will be performed when the MELOS orbiter is passing around the periareion. Such limb observations enable us to measure the vertical profiles of temperature, H_2O, HDO, and the line-of-sight wind velocity in a wide altitude range (up to 120 km, depending on the target) with a vertical resolution of 3-10 km.

Though the current basic design of FIRE/MELOS is optimized for the temperature sounding with the disk-mapping mode, we also discuss potential capability of FIRE for an extended sense of the Martian science: Its powerful ability to measure the diurnal variation of atmospheric minor gases promises new insight to Martian atmospheric chemistry; and the high sensitivity to the upper atmosphere will help us to understand the atmospheric escape on Mars.

Keywords: Mars, MELOS, FIRE, submillimeter-wave sounder

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A calculation of heating rate due to dissociative recombination in the Martian thermosphere

TERADA, Kaori[1*]

[1]Dept. Geophys., Tohoku Univ.

Dissociative recombination of molecular ions is one of the most exothermic reactions in the Martian thermosphere. The heating efficiencies in the terrestrial planet were calculated by several authors and they show dissociative recombination of O_2^+ is major heat source in the upper thermosphere. Recently, the energy relaxation rate of hot oxygen atoms in collisions with atmospheric oxygen gas was evaluated using realistic differential cross section, in which all the electronic energy curves of O_2 separating to the atomic ground states was incorporated. The escape probabilities of hot O due to dissociative recombination of O_2^+ for several production altitudes calculated using this realistic differential cross section show the bulk of the escape O arises from far below the exobase where it was previously believed that fast particles were thermalized immediately.

In this paper, I evaluate heating rate due to dissociative recombination using Direct Simulation Monte Carlo model. Because we do not have all the potential of the excited levels of all species, I use the Lennard-Jones potential for interaction between two molecules.

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Re-estimation of the lithospheric thickness of the volcanic areas on Mas

Mitsuyoshi Usami[1], IMAKI, kousuke[1], OGAWA, Yoshiko[1*]

[1]CAIST/ARC-Space, Univ. of Aizu

We re-estimated the potential range of the lithospheric thickness of Mars by reconsidering the possible variety of the crustal density. We used the gravity data from MRO (Mars Reconnaissance Orbiter): jgmro_110b2_anom_095.img, and topographic data from MOLA (Mars Orbiter Laser Altimeter / Mars Global Surveyor): megt90n000cb.img. Both data are provieded as grided-data with spatial the resolution of 0,25-1 degrees. The density of the crust was assumed to vary from 2700 to 3100 kg/ mˆ3. In this study, we focus on the lithospheric thickness of the volcanic areas on Mars to compare with the previous studies such as McKenzie et al. [2002].

Keywords: lithosphere, crust, Mars, admittance, gravity, topography

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Experimental constraints on the size of Martian liquid core

NAKATSUKA, Asumi[1*], URAKAWA, Satoru[1], TERASAKI, Hidenori[2], NISHIDA, Keisuke[3], Kentaro Uesugi[4], Ken-ichi Funakoshi[4]

[1]Okayama Univ., [2]Osaka Univ., [3]Tohoku Univ., [4]JASRI

Internal structure of Mars has been reported based on high-pressure mineralogical study at the mantle condition (e.g., Kamaya et al., 1993 ; Bertka and Fei 1998). Information of density of iron alloy at the Martian core condition strongly constraints the core size. In previous studies, the size of the Martian core has been estimated from density of solid iron-alloys. However, precise determinations of the moment of inertia and solar tidal deformation by Mars Global Surveyor mission indicated that the present-day Martian metallic core is not completely solid. Hence, density of liquid Fe-alloy is indispensable to estimate the Martian internal structure. Here we report the results of experimental study on the density of liquid Fe-Ni-S alloy at high pressures and estimate the internal structure of Mars.

The density of solid / liquid Fe-Ni-S was measured by X-ray absorption method combined with X-ray micro-tomography technique at high pressure and temperature. The density measurements were carried out up to 6.7 GPa and 1357 K using the tomography press at BL20B2 beamline, SPring-8.

Density of liquid Fe-Ni-S increases from 5.3 to 6.5 g/cm^3 with pressure (0.3 to 5.9 GPa). Isothermal bulk modulus (K_T) is estimated to be 25 GPa by fitting the density data to Vinet equation of state, assuming that its pressure derivative (K') is 4.

Based on the obtained density of liquid Fe-Ni-S and mantle mineralogy data (Bertka and Fei, 1998), we made the models of the internal structure of Mars that satisfy its mass and the observed moment of inertia. Radius of the Martian liquid core is ranged from 1600 to 1700 km with the crust size of 25-100 km. This suggests that there is no Mg-perovskite layer at the base of Martian mantle if Mars has a liquid core of Fe-Ni-S.

Keywords: Mars, liquid coreMars, Fe-Ni-S density, tomography, perovskite

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Cessation of early Martian dynamos due to subcriticality

HORI, Kumiko[1*], Johannes Wicht[2]

[1]National Institute for Environmental Studies, [2]Max-Planck Institute for Solar System Research

Mars has no active dynamo action at present, but likely had one in the early stage of its history. Clarifying why and how ceased is a challenging question. Several different scenarios have been proposed so far; here we explore the possibility that the dynamo stopped operating due to its subcritical nature. The presence of a strong magnetic field modifies the convective structure, mainly due to a balance between Lorentz and Coriolis forces. This modification can guarantee dynamo action at smaller Rayleigh numbers, where a weak seed field may simply decay, i.e. it can lead to a subcritical situation. Former studies suggested that the subcritical regime is rather narrow, indicating that it may therefore not play an important role for the cessation.

Here we show that a more appropriate model for the early Martian dynamo yields a much wide subcritical regime than previously reported. Even today Mars may not have developed a solid inner core so that the early dynamo was purely driven by secular cooling. The thermal temperature gradient in the conductive state is steepest at the core-mantle boundary (CMB), and hence the convection is strongly affected by the respective thermal boundary condition. Constant heat flux rather than constant temperature conditions should be used here. These more realistic conditions favor a strong magnetic field, which in turn leads to much larger convective length scales than for a weak or non-existing magnetic field. This strongly modified convection allows to lower the Rayleigh number significantly below the point where a weak seed field would start to grow. This increased extend of the subcritical regime makes it more likely that this effect may have played a role in the shutdown of the early Martian dynamo.

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Numerical modeling of impact-induced tsunami on Mars and possible sedimentological traces of an ancient Martian ocean.

IIJIMA, Yasutaka[1*], GOTO, Kazuhisa[2], MINOURA, Koji[1], Goro Komatsu[3], Fumihiko Imamura[4]

[1]Graduate School of Science, Tohoku Univ., [2]PERC, Chiba Institute of Technology, [3]IRSPS, Univ. G.d'Annunzio, [4]DCRC, Tohoku Univ.

The ancient ocean hypothesis on Mars was first proposed in the late 1980s based on geomorphological evidence interpreted in Viking orbiter images (Parker et al., 1989), which had too low spatial resolution to discuss detail geomorphology. Since then, resolution of satellite images has improved, and now 30-cm resolution HiRISE (High Resolution Imaging Science Experiment) images enable us much more detail sedimentological observations (e. g. McEwen et al., 2007). Comparison of sedimentological features of Mars and the Earth may provide new clues for the past existence of Martian ocean(s).

However, on Mars, sedimentological features of the oceans and shorelines may differ from those on the Earth because of lack of a tidal activity, which is a large factor characterizing terrestrial shorelines (Dohm et al., 2009). One phenomenon that is in common on Mars and the Earth as well and that can leave sedimentological traces on the surface of the planets is meteorite impact into oceans and consequent generation of large tsunami waves. In order to propose candidate localities to find sedimentological evidence of the impact-generated tsunami, we conducted numerical modeling for tsunami propagation and inundation on the surface of Mars.

We conducted numerical simulation using the MOLA (Mars Orbiter Laser Altimeter) topographic data. Simulations are based on the nonlinear long wave theory, and a leap-frog scheme was used. According to the simulation, velocities are low at the deep sea region (0 to 2 m/s) but are high at around the impact-produced crater and the shoreline (4 to 12 m/s) if we assume 50 km for the crater diameter. Velocities along the shoreline differ depending on the regions because of the differences in geomorphological features or of the presence of various craters. The numerical simulation indicates that the tsunami effects are strong mostly around the crater and the shoreline, which should be the candidate places to explore the sedimentological traces of the tsunami.

Erosion and sedimentation is the main sedimentological process of tsunami that leaves possible trace of the tsunami. Tsunami sedimentation is divided into sedimentation of sand deposit, and transport and sedimentation of boulders. In these features, movement of boulders is the most adequate candidate as a trace of tsunami on Mars, because erosional and depositional features preserved in sedimentary layers are difficult to find on Mars with satellite images, whereas boulders placed on the surfaces of Mars are visible with high resolution satellite images such as HiRISE. Furthermore, the current velocity calculated along the shoreline (˜12 m/s) is high enough to move meters-scale long boulders (˜4 m/s for movement of 4 to 5 m long boulders) on Mars. Therefore, although boulders may be originally deposited concentrically around impact craters, they might have been reworked by tsunami wave currents if an ocean existed in the past. Thus, we propose that the reworked boulder deposits may be the best candidates as the sedimentological trace of ancient oceans on Mars.

Keywords: Mars, Satellite images, Boulder

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Global distribution of volcanic cones associated with recent Martian magmatism

NOGUCHI, Rina[1*], KURITA, Kei[1]

[1]Earthquake Research Institute, The University of Tokyo

Martian magmatism within recent several hundreds of millions years is still inside the certain of enigma. Enormous numbers of small cone have been identified in wide range of areas mostly on the Amazonian surface by high resolution imagings [e.g. Fagents and Thordarson, 2007, Jaeger et al., 2007]. In many cases they can be interpreted as scoria cones and rootless cones, which indicate existence of recent magmatic activity [e.g. Jaeger et al., 2010, Hamilton et al., 2011].

Volcanic cones on Mars have various morphological characteristics. For example, cones in Athabasca Valles have a second cone inside the summit vent. This structure named as double cone structure [Noguchi and Kurita, 2011a] is common in Athabasca Valles and Lake Myvatn, Iceland [Noguchi and Kurita, 2011b]. It is considered that Athabasca Valles was under lacustrine environment and covered with hot lava in the recent past, which generated a lot of rootless cones in this area.

Throughout Noachian and Hesperian, intensive activity of shield volcanism was evident. By connecting these change of the style of volcanism is suggested by Kurita and Ohmori, 2011; from concentrated large volcanic edifice forming eruption to small but wide-spread flood type eruption. In this presentation we report global distribution of cone morphology by extensive survey of high resolution images. We found several new locations having cone morphology, which have not been described before. As a whole, clustering near the dichotomy boundary seems evident.

Keywords: Mars, magmatism, cone, scoria cone, rootless cone

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Characteristics of impact ejecta and crater lake of Lonar Crater, India: a terrestrial analogue of Martian impact crater

CHANG, Yu[1*], SEKINE, Yasuhito[2], GOTO, Kazuhisa[3], Goro KOMATSU[4], Senthil P. Kumar[5], NAKAMURA, Atsunori[6], TAJIKA, Eiichi[2], YOKOYAMA, Yusuke[6], MATSUI, Takafumi[3]

[1]Earth and Planetary Sci., Univ. of Tokyo, [2]Complexity Sci. & Eng., Univ. of Tokyo, [3]PERC, Chiba Institute of Technology, [4]IRSPS, Univ. G.d'Annunzio, [5]National Geophysical Research Institute, India, [6]AORI, Univ. of Tokyo

Lonar crater, emplaced in the Deccan traps in India, is a 1.88-km-diameter simple impact structure. As the target rocks of the Lonar crater are basalt, it is a good analogue of simple craters on the surfaces of other terrestrial planets, such as Mars. In particular, because the formation age of the crater is very young (i.e., ˜52 ka or ˜660 ka), the morphology of rampart-type ejecta blanket is preserved around the Lonar crater. The Lonar crater is the only known impact structure on Earth where active hydrological cycles maintain a lake on the crater floor. Accordingly, knowledge on the formation mechanisms of both the Lonar crater and its crater lake would provide a unique opportunity to understand surface environments and habitability of ancient Mars.

In this study, we report results of our geological survey for the Lonar crater, particularly focusing on the characteristic features of ejecta deposits and water supply to the crater lake. On the basis of the results, we will discuss the implications for the formation mechanisms of the rampart craters and crater lakes on ancient Mars.

Keywords: Lonar crater, ejecta, Mars, crater lake, rampart

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Slope analyses of massive landslides on Valles Marineris, Mars

Ryosuke Kurahashi[1], DEMURA, Hirohide[2*], OGAWA, Yoshiko[2], ASADA, Noriaki[1]

[1]Dept. Computer Science & Engineering, The University of Aizu, [2]CAIST/ARC-Space, Univ. of Aizu

Valles Marineris (VM) is a system of large troughs in the equatorial region of Mars. VM extends over 4,000 km from west to east, with individual troughs up to 11 km in depths, 250 km in widths, and over 1,000 km lengths. Many processes have been hypothesized to explain the geometry and formation of the troughs, including tectonic, collapse, and erosional mechanisms [e.g., Sharp, 1973; Tanaka and Golombek, 1988; Schultz, 1991].

VM consists of a number of large-scaled troughs suggesting massive landslides. We foucused on such features and conducted an analytical survey based on the altimetry data from Mars Orbiter Laser Altimeter (MOLA) onboard Mars Global Surveyor. We used the gridded data of MOLA with spacial resolution of 1/128 degree/pix and a software called GRIDVIEW developed by Roark et al. [2004].

We examined the slopes of individual troughs on the north wall and south wall of VM, respectively. The trough areas consist of multiple planes. We picked up the planes of $>$ 5km in representative scale considering the resolution of MOLA gridded data. We divided each landslide-like area into 3 sections; alcove (collapse or fall), channel (erosion) and talus (deposition), referring to the image map of Mars and also partly checking the image data from HiRISE. Then we measured each slope of the sections.

We observed the slopes of the alcoves are almost same between both walls, which suggests no difference of material strength and fall mechanism between the north and south walls. We also found the upper limit of the slope of the talus and the lower limit of that of the alcove are both 20-25 degrees. This fact suggests that the angle of repose on Mars are likely more than 10 degrees lower than 34 degree indicated by Chojnacki et al. [2010], which could be explained by considering the involution of the ancient air at VM on Mars.

Keywords: Mars, Valles Marineris, Landslide, Angle of repose, Morphology, Data analysis