Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

PPS03-01 Room:105 Time:May 24 10:45-11:00

Current status of MELOS1 Mars exploration planning

SATOH, Takehiko[1*], KUBOTA, Takashi[1], MIYAMOTO, Hideaki[2], IMAMURA, Takeshi[1], OKADA, Tatsuaki[1], ISHIHARA, Yoshiaki[3], YAMAGISHI, Akihiko[4], Kazuhisa Fujita[1], Akira Oyama[1], Goro Komatsu[5]

[1]Japan Aerospace Exploration Agency, [2]University of Tokyo, [3]National Astronomical Observatory of Japan, [4]Tokyo University of Pharmacy and Life Sciences, [5]The G. d'Annunzio University

MELOS (an acronym of Mars Exploration with Lander-Orbiter Synergy) is Japan's new and ambitious plan for a series of Mars exploration missions. The ultimate goal of the MELOS series missions is to understand the solid planet, the surface processes, the atmosphere, and its surrounding plasma environment as one integrated system. This, of course, requires multiple missions of orbiters and landers, equipped with various instruments. The first of the MELOS series, MELOS1, is currently under planning. The mission consists of two elements: an orbiter and an entry-descent-landing (EDL) demonstrator. The scientific objective of the orbiter is the spatial and temporal variability of Martian dust, which have significant effect on the Martian climate through a variety of processes, such as heating of atmosphere by absorption of the sunlight, etc. To continuously monitor the evolution of dust storms, the orbit (near equatorial, as opposed to polar orbits in most missions) is so designed (1) that enables the orbiter nearly in synchronization with the planet's rotation when it is around the apocenter, and (2) that the apocenter's local time is always maintained near the noon. The instruments on board MELOS1 include the imaging polarimeter (visible wavelengths), the thermal-infrared camera, the sub-mm sounder, plus the ultra-stable oscillator for the radio occultation science. The EDL demonstrator will primarily perform experiments of engineering aspects, while a small portion of its payload will be available for scientific experiments. Current proposals include the interior-structure study, the astro-biological experiments, and the surface-geology study. The selection will take place in this year and the MELOS1 mission will be proposed for the launch around 2020. We welcome inputs from the world Mars science community and/or contributed instruments that require and benefit from MELOS1's unique orbit.

Keywords: Mars exploration, dust, meteorology, life on Mars, interior structure, surface geology

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

PPS03-02 Room:105 Time:May 24 11:00-11:15

MELOS Mars meteorological orbiter concept

IMAMURA, Takeshi[1*], OGOHARA, Kazunori[1]

[1]Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency

A Mars mission concept MELOS (Mars Exploration with Lander and Orbiter Synergy) is now being developed in Japan. As a part of this mission, we propose a Mars orbiter dedicated to meteorological study, focusing on dust transport. Water cycle and photochemistry will also be addressed.

Keywords: Mars, atmosphere, meteorology, exploration

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

PPS03-03 Room:105 Time:May 24 11:15-11:30

Water isotopic ratio in the Mars atmosphere: observational plan and simulation using a general circulation model

KURODA, Takeshi[1*], SAGAWA, Hideo[2], KASAI, YASUKO[2], KASABA, Yasumasa[1]

[1]Department of Geophysics, Tohoku University, [2]National Institute of Information and Communications Technology

Though the current Mars is a dry planet, there are many topographic evidences of past liquid water flow. Where has the surface liquid water gone? Some of the water is thought to have escaped into space, while some seems to have moved to the polar regions and underground. The detection of HDO/H_2O ratio in the atmosphere and on/under the surface of Mars should provide a good information as an index of the origin of water which shows the history of water cycle and escape processes which connents to the long-term climate change of Mars. Moreover, the mapping of HDO/H_2O ratio has been done for terrestrial atmosphere to visualize the physical processes on the water cycle, and we expect that the mapping of the ratio on Mars will also reveal the water cycle in current Mars environment, especially the moving in and out between atmosphere and surface. The sub-millimeter sounder FIRE (Far Infra-Red Experiment) onboard the MELOS meteorological orbiter (planned to be launched around 2020) plans the first observation and mapping of HDO/H_2O ratio from the Mars orbit. In addition, the 3-dimensional simulations of the HDO and H_2O cycles using a Mars general circula-tion model (DRAMATIC MGCM) are ongoing for the data assimilation of the FIRE/MELOS data. In this presentation we will show the description and numerical results of the simulations, and discuss the plan of scientific investigations together with the observation by FIRE/MELOS.

Keywords: Mars, water cycle, isotopic ratio, sub-millmetre sounder, General circulation model

Japan Geoscience Union Meeting 2012
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PPS03-04 Room:105 Time:May 24 11:30-11:45

Trial of infrared high-spectral resolution spectrocopy for Mars and Planets: Current studies in Tohoku Univ.

KASABA, Yasumasa[1*], NAKAGAWA, Hiromu[1], AOKI, Shohei[1], MURATA, Isao[1], OKANO, Shoichi[2], KASAI, YASUKO[3], SAGAWA, Hideo[3]

[1]Dep. Geophys., Tohoku Univ., [2]PPARC, Tohoku Univ., [3]NiCT

Mid-high spectral resolution spectroscopy revails us minor components and dynamics of planetary systems. We Tohoku University group has tried to apply this technique mainly by three methods.

The first is the space observations from orbiters (see Aoki et al., in this meeting). We have investigated the Mars Express (MEX) Planetary Fourier Spectroscopy (PFS) data for several years under the collaboration with Italian groups. In 2004, MEX/PFS team found CH4 in the Martian atmosphere (Formisano et al., 2004). Associated with its spatial anisotropy and time variations, the loss mechanism by oxidant component becomes important. We analyzed the data and concluded that the oxidant in the atmosphere is insufficient for the support of CH4 time and spatial variations suggested by several observations. As the next target, we just started to investigate the vertical profile of CH4 by same instruments.

The second is the ground-based observations (see Aoki et al., in this meeting). We have investigated the SO and SO2 abundances in the Martian atmosphere by submm observations. In all results, we could not find any signature of gas produced from the crust, which would suggest that the origin of CH4 is not volcanic-like crust activities. In Nov 2011, Jan 2012, and Apr 2012, we also used SUBARU IRCS for the simultaneous observation of Martian CH4 lines. This observation aims the areas where the enhancement of CH4 was reported in past observations from ground (low-latitude region) and from MEX/PFS (polar region) in different Martian season. The preliminary result will be shown in the meeting.

The last is the instrument development (see Nakagawa et al., in this meeting). We have developed a ultra-high spectral resolution spectrometer, called MILAHI (Mid-Infrared LAser Heterodyne Instrument), for 7-11 um wavelength at a resolution of up to 10^{7-8} and a bandwidth of 1GHz. In Sep 2011 and Jan 2012, the test equipment was mounted on the Higashi-Hiroshima 1.5m telescope to perform test observations with Moon, Venus, and stars. Unfortunately, the final success was prevented by bad weathers, but the observed S/N told us that we should get the Venus and Mars spectrum with this design. We just finish the development phase of this project.

Although a telescope dedicated to this instrument does not exist yet, we expect to attach it to the PLANETS telescope at the top of Mt. Haleakala, Maui island, Hawaii, which is now in development with Univ. Hawaii, Tohoku Univ., Kippenhauer Inst., National Univ. of Mexico, Univ. Turku, Harlingten Inovative Optics Co., Stan Truitt Breckenridge Astronomycal Ltd, and collaborators (see Okano et al., in this meeting). Its first light is, if all things are going well, in 2014.

Keywords: Mars, infrared, spectroscopy, CH4, velocity field, new telescope

Japan Geoscience Union Meeting 2012
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PPS03-05 Room:105 Time:May 24 13:45-14:00

Two-dimensional simulation of Martian atmospheric convection with the major component condensation over CO2 ice surface

YAMASHITA, Tatsuya[1*], ODAKA, Masatsugu[1], SUGIYAMA, Ko-ichiro[2], NAKAJIMA, Kensuke[3], ISHIWATARI, Masaki[2], TAKAHASHI, Yoshiyuki O.[4], NISHIZAWA, Seiya[4], HAYASHI, Yoshi-Yuki[4]

[1]Hokkaido Univ., [2]Hokkaido Univ. / CPS, [3]Kyushu Univ., [4]Kobe Univ. / CPS

We have been developing a two-dimensional cloud resolving model and performing numerical simulations for the purpose of investigating characteristics of convection with condensation of the major component(e.g. Yamashita et al., JPGU 2011). In the system where the major component condenses, as a low temperature limit, a state where the surface is covered with the ice of the atmospheric major component can develop. The Martian polar night approximately corresponds to this state, therefore understanding of the Martian polar night contributes to elucidation of the behavior of the system where the major component condenses.

The observation by MOLA suggested that atmospheric major component, CO_2, condenses to form ice cloud in Martian polar region (Pettengill and Ford, 2000). Colaprete et al.(2003) proposed that some of the clouds are formed by convective motions. However, in the system that the major component condenses, the temperature profile of both an ascending air parcel and the surrounding environment follow the moist adiabat, and the air parcel cannot gain buoyancy. Therefore convection with condensation of the major component cannot occur. If the value of critical saturation ratio is greater than 1.0, there is a possibility that convective motions occur(Colaprete et al., 2003). Furthermore, falling cloud particles drag the surrounding air, and this effect can affect the convective motion. In this work, we report the preliminary numerical simulation where surface boundary condition, thermal forcing, and the formulation of cloud microphysics appropriate for the environment over the Martian polar cap are introduced.

The governing equations are based on the quasi-compressible equations(Klemp and Wilhelmson, 1978) and a conservation equation of solid CO_2. In cloud microphysics, the effects of gravitational settling and drag of cloud particles are considered. We set the initial surface pressure and the values of critical saturation ratio to be 7 hPa, 1.0, respectively. The model atmosphere is subjected to an externally-given thermal forcing that is a substitute for the radiative cooling. Because there is no solar radiation in the actual polar night, we do not give any heating, and we give horizontally uniform cooling from 1 km height to 15 km height. The cooling rate is set to be -5.0 K/day. The initial temperature profile is given such that saturation ratio is 0.98(Colaprete et al., 2003) below 15 km height, and isothermal(135 K) above 15 km height. Because the surface temperature of the actual polar cap is expected to be nearly sublimation temperature of CO_2, the air temperature at lower boundary is fixed to be initial value (about 150 K). Random potential temperature perturbations whose amplitudes are 1K are given at the lowest grid point to seed convective motion at initial time. The computational domain is 50 km in the horizontal direction and 20 km in the vertical direction. The spatial resolution is 200 m in both the horizontal and vertical directions. Time integration is 30 days.

The statistical equilibrium state has been established at 30 days. In the statistical equilibrium state, a cloud layer is formed in the uniform cooling region, and there strong convection does not occur except for near the surface. Specifically, a cloud layer is formed below 15 km height, and the density of cloud is maximum at about 2 km height. Vertical motions whose amplitudes are more than 1.0 m/s are found only below 2 km height, and the maximum value of the amplitudes is about 3.0 m/s. The convection found below 2 km height is driven by the effect of drag of cloud particles. Since laboratory experiments suggested that critical saturation ratio of 1.35 are required under the temperature and pressure in Martian polar region(Glandorf et al., 2002), we are also going to report about the case that critical saturation ratio is 1.35 in our presentation.

Keywords: condensation of major atmospheric component, carbon dioxide ice cloud, cloud resolving model

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PPS03-06 Room:105 Time:May 24 14:00-14:30

Glaciation of Mars from 10 million years ago until 10 million years into the future simulated with the model MAIC-2

GREVE, Ralf[1*], Bjoern Grieger[2], Oliver J. Stenzel[3]

[1]Hokkaido University, [2]European Space Astronomy Centre (ESAC), [3]Max Planck Inst. for Solar System Res.

The Mars Atmosphere-Ice Coupler MAIC-2 is a simple, latitudinal model that consists of a set of parameterizations for the surface temperature, the atmospheric water transport and the surface mass balance (deposition minus sublimation) of water ice. It is driven directly by the orbital parameters obliquity, eccentricity and solar longitude (Ls) of perihelion. Surface temperature is described by the Local Insolation Temperature (LIT) scheme, which uses a daily and latitude-dependent radiation balance. The sublimation rate of water is calculated by an expression for free convection, driven by density differences between water vapor and ambient air, the deposition rate follows from the assumption that any water vapour which exceeds the local saturation pressure condenses instantly, and atmospheric transport of water vapour is approximated by instantaneous mixing. Glacial flow of ice deposits is neglected. Simulations from 10 million years (Ma) ago until 10 Ma into the future (with an additional spin-up from 20 to 10 Ma ago) predict a variable glaciation with two distinct stages. Stage 1, the period of high average obliquity prior to 4 Ma ago, is characterized by ice thicknesses less than 400 m and a very mobile glaciation all over the planet. During stage 2, from 4 Ma ago until today, the north and south polar ice deposits grow essentially monotonically; however, interrupted by significant sublimation events at ˜3.2, 1.9 and 0.7 Ma ago (when maximum amplitudes of the main 125-ka obliquity cycle occur). The growth of the polar deposits is predicted to continue into the future.

Keywords: Mars, Planetary ice, Ice cap, Polar layered deposits, Modelling

Japan Geoscience Union Meeting 2012
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PPS03-07 Room:105 Time:May 24 14:30-14:45

Analog experiments of formation of the spiral troughs on Mars' North Polar Layered Deposits: cyclic steps on ice

YOKOKAWA, Miwa[1*], IZUMI, Norihiro[2], SHIMIZU Hiroki[1], NAITO, Kensuke[2], Tomohito Yamada[2], GREVE, Ralf[3]

[1]Osaka Institute of Technology, [2]Faculty of Engineering, Hokkaido University, [3]Institute of Low Temperature Science, Hokkaido University

The spiral troughs observed on the Mars' North Polar Layered Deposits (NPLD) show intriguing features that contain a detailed stratigraphic record of surface processes in Mars' recent polar history. SHARAD radar data showed that the troughs have migrated as much as 65 km towards the north during the accumulation of the uppermost ~ 600 m of NPLD (Smith and Holt, 2010). Though they are suspected to have some relation with katabatic wind blowing on the ice cap, it has not been known how the spiral troughs are formed in detail. Considering that the troughs are formed perpendicular to the direction of katabatic wind, they are assumed to be boundary waves rather than streak-like configurations such as rills and gullies. From features that the step length is much larger than the step height, and that internal structures show traces of upstream migration (Smith and Holt, 2010), the spiral troughs may possibly be cyclic steps formed by a density current created by cooling of the atmosphere due to ice. Cyclic steps are spatially periodic bedforms where each wavelength is delineated by an upstream and downstream hydraulic jump. They migrate upstream keeping the same wavelength. Recently cyclic steps have been reported from various environments on the Eargh, such as fluvial and deep-sea settings, and in various bed materials, such as bedrock, non-cohesive sediments, and cohesive sediments (e.g., Kostic et al., 2010). Smith et al (2011) have demonstrated that numerical simulation with a cyclic step model can show reasonable consistency with an observed migration rate. In this study, we have performed a series of physical experiments analogous to the formation of cyclic steps on ice by density currents.

The experiments were conducted using the cold laboratory of the Institute of Low Temperature Science, Hokkaido University. In the case of Mars, sublimation by katabatic winds results in erosion in some places and in the other places, water included in the atmosphere blowing on ice is sublimated to become ice and deposited on the bed covered with ice. In order to model this process, we used two kinds of liquid that include water but do not freeze even below the ice point. The liquids we used were (a) ethylene glycol-water solution (17 %-83 %) whose freezing point is -6.6 degrees C, (b) mixture of silicon oil (20cS) and water (9:1) whose freezing point is -0.7 degrees C. We used a 1.4 m long, 2 cm wide, and 25 cm deep flume made by plexiglass. The flume has 8 cm high weirs at the downstream end and 1.2 m upstream from the downstream end, so that there is an 8 cm deep reservoir. We put water in the reservoir and froze it so that the flume has an 8 cm ice layer on its bottom. The flume with ice bed is tilted by 5 up to 35 degrees. The liquid is supplied from a head tank to the upstream end of the flume, flows on ice in the flume, and was dropped from the downstream end into a downstream reservoir, then pumped up to the head tank. In point of temperature, everything in the room is chilled by the air of the room. The temperatures of the liquids were (a) -6.1 to -6.6 degrees C, and (b) -1.0 to 1.5 degrees C.

As a result, cyclic steps were formed under erosional conditions in series (a) and both erosional and depositional conditions in series (b). The step length is observed to be different in each case. At this moment, steps develop almost vertically, both downward and upward, and show no prominent lateral, neither up-current nor down-current, movements.

In these experiments, we demonstrated that cyclic steps can be formed on rigid ice by the fluid flowing on the ice surface. Further experiments will be needed to examine the conditions for up-current movement of cyclic steps on ice, which should lead us to understand the migration of the spiral troughs on NPLD.

Keywords: North Polar Layered Deposits on Mars, spiral troughs, cyclic steps, ice, flume experiments

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PPS03-08 Room:105 Time:May 24 14:45-15:00

Electro-magnetic measurements by MELOS lander

TAKAHASHI, Yukihiro[1*], SHIMIZU, Hisayoshi[2], ISHISAKA, Keigo[3]

[1]Dept. Cosmosciences, Hokkaido University, [2]University of Tokyo, [3]Toyama Prefectural University

No measurement of atmospheric electric field and electromagnetic waves on the ground in Mars has been made, though it could be dedicated not only to understanding of the electric current research but also to the meteorology, solid planet and space physics. DC electric filed near surface is considered to play an important role in initiating dust devil. The electromagnetic wave measurement makes it possible to know the location and the quantitative strength of dust devils wind with few observation sites. Though only one observation site enables us to determine the discharging location, two or three sites improve the accuracy significantly. This measurement also contributes to the studies both on the crust and the upper atmosphere. Though Exo Mars will carry out a simple observation of electric filed, most of the targets will remained unexplored. We propose a simple and promising instrumentation set for the DC and AC electromagnetic observation making use of MELOS lander. Here we also discuss the coordinated observation with atmospheric orbiter.

Keywords: Mars, Lander, MELOS, electro-magnetic, measurement

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PPS03-09 Room:105 Time:May 24 15:00-15:15

Current distributions and behaviors of dust and water on the surface of Mars

MIYAMOTO, Hideaki[1*], OGOHARA, Kazunori[2], IMAMURA, Takeshi[2]

[1]University Museum, University of Tokyo, [2]ISAS, JAXA

Dust and water are fundamentally important for the current status of both martian atmosphere and surface deformations. While the amount of airbone dust largely varies with seasons and the presence of dust storm, dust exists on the surface of Mars permanently through geological timescale. Theoretical studies find out that airborne dust significantly contributes to the thermodynamics of the atmosphere, which indicates that dust should play important role even in the past climatic conditions. On the other hand, the presence of dust on the surface significantly controls the condition of the martian surface in terms of such as thermal inertia, albedo, and transmittance. These are controlling factors for the formations of currently-active geological features, including as aeolian features and ice deposits, which distribute all over the surface of Mars at least as remnants. Water is a minor component for the martian atmosphere, but plays important roles for the evolutions of the regolith layer and deposits in the polar regions. The formations of water/ice-related features are resulted from the strong link between surface/subsurface reservoirs of water and atmosphere, and thus, water can be considered as an important indicator of the atmospheric transportation-mechanisms and seasonal climatic changes.

The orbiter of the MELOS mission will study martian meteorology by measuring atmospheric transportations of water and dust. The lander of the MELOS mission, which is now considered as an EDL experimental unit as a precursor of the MELOS-2 mission, may perform meteorological observation. In this talk, we will review geological aspects of dust- and water-related features to discuss the possible contribution of lander measurements for the states of airborne dust and water at the martian surface level to understand the martian meteorology and climate history.

Keywords: Mars, MELOS, dust, water, geology, atmoshere

Japan Geoscience Union Meeting 2012
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PPS03-10 Room:105 Time:May 24 15:30-16:00

Current and future exploration of the Moon and Mars: variations of rotation, shapes, displacements of center of mass

BARKIN, Yury[1*], HANADA, Hideo[2], SASAKI, Sho[2], Sander Goossens[2], MATSUMOTO, Koji[2]

[1]Sternberg Astronomical Institute, Moscow, [2]National Astronomical Observatory, Mizusawa

Actual problems of modern selenodynamics and selenodesy, Mars rotation and inner dynamics are discussed in view of achievements by geodynamics and geodesy of last years and the possibility of re-opening prospects in modern researches of the Moon and Mars with the help of space vehicles.

Altimetry and the variation of the lunar figure and center pieces. The accuracy of satellite measurements of the Moon is now so high (Goossens S., Matsumoto K. et al., 2010; Smith et al., 2010) that it is possible to set long-term objectives for the study of temporal variations of the shape of the Moon, changing its mean radius and its mean radiuses of the northern and southern hemispheres, the eastern and western hemispheres, the displacements and oscillations of its centers of mass, the secular variations of the coefficients selenopotential etc. Altimetry method most widely used to study variations in the Earth's ocean surface, as well as some stationary geometric features of shapes and figures of celestial bodies (Mercury, Mars, Titan etc.). However, the application of this method can be significantly expanded to study the deformation of temporal variations of the solid surfaces of planets and satellites (Moon, Mars, Europa and oth.).

Tidal variations of the gravitational field of the Moon and their testing according to the lunar space missions. Due to outstanding achievements of space missions to the Moon (KAGUYA, Lunar Express etc.), there are quite real the direct determinations of cyclic (and also secular) variations of selenopotential coefficients (for low harmonics), more detailed description of tidal and non-tidal deformations of a surface, in particular researches of global planetary effects in change of opposite hemispheres of the Moon and in displacement of its centre of mass.

Eccentric positions of the shells of the Moon (and Mars) and geodynamic implications. The Moon and Mars is characterized by very significant displacements in the positions of center of the figure and the center of mass is 1.9 km from the Moon (Goossens S., Matsumoto K. et al., 2010) and the phenomenal displacement of these centers is 3.3 km for Mars (Zuber et al., 1998). These observed phenomena reflect the dynamics of shells and changes in the shells of these celestial bodies in their geoevolution. There is evidence in favor of the fact that these evolutionary changes for the Moon and Mars have place in the modern epoch. New statement of a problem about librations of the Moon with the displaced (eccentric) liquid core deserves steadfast attention and is actual. Dynamic effects caused by a eccentricity of the core can be remarkable and basically can be observed at precision laser observations with millimeter accuracy.

Mars rotation. Determination of the acceleration of axial rotation of Mars and the secular drift of the pole of its axis of rotation are the actual problems of current and future space missions to Mars. We have obtained preliminary theoretical estimates of these secular effects in the rotation of Mars, based on the assumption about existence of secular relative displacements of the core and mantle of Mars in the modern epoch and secular and directed mass redistribution of this planet (Barkin, 2009). There are some confirmations of mentioned hypothesis - secular changes in the activity of natural Martian processes, including climatic changes on Mars. Because on the Mars we observe planetary processes of a general warming, redistribution of fluids from the southern hemisphere to the northern hemisphere and secular changes in other processes, that is phenomena in nature similar to processes occurring on the Earth.

The work was supported by the Russian ? Japanese and Russian - Chinese grant RFBR N 11-02-91160 and RFBR N 11-02-92113 and Russian grant RFBR N 11-05-01134.

Keywords: Mars, Moon, rotation, shape, center of mass

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(May 20-25 2012 at Makuhari, Chiba, Japan)

PPS03-11 Room:105 Time:May 24 16:00-16:15

Effects of water on Martian mantle evolution induced by magmatism and solid-state convection

YANAGISAWA, Takatoshi[1*], OGAWA, Masaki[2]

[1]IFREE, JAMSTEC, [2]Graduate School of Arts & Sciences, Univ. Tokyo

To consider the thermo-chemical evolution of Martian mantle, we present numerical models of mantle evolution including magmatism in two-dimensional box geometry. By including magmatism, our models can reproduce compositionally layered mantle structure and surface crust spontaneously, and can treat the whole evolution process consistently. The viscosity is strongly temperature-dependent, and the lithosphere is stagnant. The effect of water is included in two aspects depending on its content; decreasing the melting temperature of mantle materials, and decreasing the viscosity of the solid mantle. At the first stage of evolution, a magma ocean develops and generates a basaltic crust, a layer of compositionally buoyant residue of the crust in the uppermost mantle, and a deep-mantle compositionally denser layer, which has a higher content of the basaltic component. The magma ocean extracts most of the water initially contained in the upper layer, but some water remains in the lower layer of the mantle. Subsequently, hot plumes ascend from the lower layer to induce magmatism. The water allows plume magmatism to continue for a long duration, up to 5 Gyr depending on the initial water content and the detail of the initial temperature distribution in the mantle, provided that the mantle is initially not too hot just after planetary formation. The plume magmatism is sufficiently active to cause significant crustal growth and dehydration of the crust and mantle in the early evolutionary stage when the internal heating is strong; the amount of extracted water is equivalent to a water layer of up to several hundred meters in depth. Water can also enhance the extraction of heat producing elements from the mantle, which makes the lithosphere thicker. Both crustal growth and dehydration eventually subside as the heat producing elements decay. By comparing these results with recent studies on crustal evolution, we gain a deeper understanding of the tectonic history of Mars.

Keywords: Martian mantle, structural evolution, magmatism, water

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PPS03-12 Room:105 Time:May 24 16:15-16:30

MELOS LIFE SEARCH PROPOSAL: SEARCH FOR MICROBES ON THE MARS SURFACE WITH SPECIAL INTEREST IN METHANE-OXDIZING BACTERIA

YAMAGISHI, Akihiko[1*], YOSHIMURA, Yoshitaka[2], HONDA, Hajime[3], MIYAKAWA, Atsuo[4], NAGANUMA, Takeshi[5], OHNO, Sohsuke[6], ISHIMARU, Ryo[6], SASAKI, Sho[7], KUBOTA, Takashi[8], SATOH, Takehiko[8], MIYAMOTO, Hideaki[9]

[1]Depart. Mol. Biol., Tokyo Univ. Pharm. Life Scie., [2]Tamagawa University, [3]Department of Bioengineering, Nagaoka Univ. Tech., [4]Shizuoka University, Faculty of Engineering,, [5]Hiroshima University, [6]Planetary Exploration Research Center, Chiba Institute of Technology, [7]National Astronomical Observatory of Japan, [8]ISAS/JAXA, [9]The University Museum, The University of Tokyo

Among the planets and giant satellites in our solar system, the characteristics of Mars are most similar to those of Earth. This may suggest that it may be possible for life similar to terrestrial life to arise and to survive on Mars. We propose to search for microbes on Mars, 5 to 10 cm below the surface. The first effort should be to identify locations where methane is emitted from underground. The rover will approach the methaneemitting site, where soil will be collected and analyzed. A combination of fluorescent dyes will be used to detect candidate cells using a fluorescence microscope[10]. Possibly in another mission, putative cells will be hydrolyzed and analyzed by HPLC and/or mass spectral analysis to define the characteristics of the candidate cells, which will indicate the origin of the candidate cells.

Keywords: MELOS, Mars, Life search, Fluorescence microscope, Methane oxidizer

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PPS03-13 Room:105 Time:May 24 16:30-16:45

Most essential factor of the habitable Earth: initial ocean volume 3-5km thick

MARUYAMA, Shigenori[1*]

[1]Tokyo Institute of Technology

Considering the size of ecosystem on the Earth, one at deep-sea hydrothermal system and another on the surface, and history of life in relation to the emergence of the second system after 800-600Ma, it is concluded that the fate of life system on the Earth was determined to be initial ocean mass that was extremely tight constraint as 3-5 km thick. The planet Earth has lost water into mantle 4.0 b.y after the birth, because of cooling. Appearance of huge landmass above sea-level caused the global dispersion of nutrients by rivers and winds, driven by Sun which drives the material circulation of the system. If the value is 1km more than this limit, the metazoans have not yet appeared on the Earth. If the initial mass was smaller than 2.5km, plate tectonics did not operate to increase nutrients-enriched TTG crust on the Earth. No evolution of life is expected, even if it was born.

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PPS03-P01 Room:Convention Hall Time:May 24 17:15-18:30

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

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

PPS03-P02 Room:Convention Hall Time:May 24 17:15-18:30

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

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

PPS03-P03 Room:Convention Hall Time:May 24 17:15-18:30

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

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

PPS03-P04 Room:Convention Hall Time:May 24 17:15-18:30

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

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

PPS03-P05 Room:Convention Hall Time:May 24 17:15-18:30

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

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

PPS03-P06 Room:Convention Hall Time:May 24 17:15-18:30

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.

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

PPS03-P07 Room:Convention Hall Time:May 24 17:15-18:30

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

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

PPS03-P08 Room:Convention Hall Time:May 24 17:15-18:30

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

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

PPS03-P09 Room:Convention Hall Time:May 24 17:15-18:30

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.

Japan Geoscience Union Meeting 2012
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PPS03-P10 Room:Convention Hall Time:May 24 17:15-18:30

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

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

PPS03-P11 Room:Convention Hall Time:May 24 17:15-18:30

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

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

PPS03-P12 Room:Convention Hall Time:May 24 17:15-18:30

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

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

PPS03-P13 Room:Convention Hall Time:May 24 17:15-18:30

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