

MELOS1 火星探査検討の現状 Current status of MELOS1 Mars exploration planning

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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.

キーワード: 火星探査, ダスト, 気象, 火星生命, 内部構造, 表層地質

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

MELOS 気象オービター構想 MELOS Mars meteorological orbiter concept

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火星気候システムの核心部分である大気ダストの輸送プロセスの解明を軸に、火星大気が内在する様々な変動、大気と地殻をめぐる水の循環、微量ガスの動態に迫る火星オービターを、MELOS計画の中心ミッションとして提案する。近年の火星探査の多くが低高度の極軌道を採用してきたのと対照的に、あえて赤道周回の楕円軌道を取り、高い空間分解能かつ時間的に連続的な偏光観測、サブミリ波観測、熱赤外観測を行い、エアロゾル・微量ガス・気温場の3次元グローバル分布を得る。このことにより、これまで見ることができなかった物質循環の素過程を可視化する。

キーワード: 火星, 大気, 気象, 探査

Keywords: Mars, atmosphere, meteorology, exploration

火星大気における水同位体比の観測計画と大気大循環モデルを用いたシミュレーション Water isotopic ratio in the Mars atmosphere: observational plan and simulation using a general circulation model

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現在の火星地表面は非常に乾燥しているが、その一方で過去には液体の水が潤沢に存在していたことを示唆する地形が数多く観測されている。その水の一部は現在極域の氷床や地下氷(水)として存在する一方、多くの水が太陽風により宇宙空間に散逸されたと考えられている。現在火星の大気中に水蒸気や氷雲として、また氷床などの表層環境に存在する水の HDO/H₂O 比はそれらの起源を示す指標となり、火星の気候変動に伴う水循環や大気散逸を探る上で重要な情報となる。また HDO/H₂O 比の測定は地球大気においても水循環における物理プロセスの可視化に使われており、よって火星でも HDO/H₂O 比の分布を知ることによって現在の環境における水循環の様子、特に地表~大気間の水蒸気の出入りの様子が見えてくることが期待される。2020年頃の打ち上げが検討されている日本の火星探査機・MELOS 気象オービタに搭載予定のサブミリ波サウンダ FIRE (Far Infra-Red Experiment) では、世界で初めて火星周回軌道から HDO/H₂O 比の3次元分布とその時間変化を測定し、詳細なマッピングを行うことを計画している。そしてデータ同化シミュレーションを通してその観測データを理論的に解釈するツールとして、火星大気大循環モデル DRAMATIC MGCM を用いた HDO および H₂O 循環の3次元シミュレーションを行っている。本発表ではそのシミュレーションの方法と計算結果を提示し、FIRE/MELOS による観測と共同で取り組むサイエンスについて議論を行う。

キーワード: 火星, 水循環, 同位体比, サブミリ波サウンダ, 大気大循環モデル

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

火星及び惑星の赤外線高分散分光観測の試み：東北大の現況 Trial of infrared high-spectral resolution spectroscopy for Mars and Planets: Current studies in Tohoku Univ.

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Mid-high spectral resolution spectroscopy reveals 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 μ m 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, Harlingen Inovative Optics Co., Stan Truitt Breckenridge Astronomical Ltd, and collaborators (see Okano et al., in this meeting). Its first light is, if all things are going well, in 2014.

キーワード: Mars, infrared, spectroscopy, CH₄, velocity field, new telescope

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

火星主成分凝結対流の二次元数値実験 –CO₂ 凍結表面上の場合– Two-dimensional simulation of Martian atmospheric convection with the major component condensation over CO₂ ice surface

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我々は火星における主成分凝結を伴う対流の性質を調べることを目的とし、2次元雲解像モデルの開発と、それを用いた長期間の計算を行ってきた(例えば山下他, 2011年連合大会)。この様な系の低温側の一つの極限は、大気主成分の凍結物により地表が覆われた状態であるが、火星極夜はこの状態とある程度近似しており、その理解は主成分凝結大気の振る舞いの解明に寄与する。

火星の極冠上空では大気主成分であるCO₂が凝結し、氷雲を形成することが知られている(Pettengill and Ford, 2000)。氷雲の中には対流で形成されたものも存在することが示唆されている(Colaprete et al., 2003)。しかし主成分が凝結する系では、雲層の上昇域、下降域の温度分布は飽和蒸気圧曲線に拘束され等しくなり、気塊は浮力を得られず、対流性の雲は生じないことになる。それでも、臨界飽和比が1.0より大きければ、対流が生じる可能性があることが示唆されている(Colaprete et al., 2003)。さらに、ここで新たに指摘すべきこととして、凝結物が重力沈降により気相から非保存的に分離し、周囲の気相を引きずることも、対流運動を駆動する可能性がある。そこで本研究では、火星極冠環境的な境界条件、熱強制の与え方で、雲微物理の定式化を変更して行なった主成分凝結対流の予備的な数値実験について報告する。

モデルの基礎方程式として準圧縮方程式(Klemp and Wilhelmson, 1978)にCO₂固相の保存式を組み合わせたものを用い、雲粒の重力落下、引きずりの効果を考慮する。臨界飽和比は1.0、地表面気圧は7 hPaとする。放射過程は陽に解かず、放射を模した熱強制を与える。極夜では太陽放射が存在しないので、加熱は与えず、高度1 kmから15 kmに冷却率-5.0 K/dayの水平一様冷却を与える。初期温度は高度15 kmより下で飽和比が0.98となるように(Colaprete et al., 2003)、それより上で135 Kとする。極冠の表面温度はCO₂の昇華温度に拘束されると考えられるので、下部境界の温度は初期値(約150 K)に固定する。初期擾乱として、下部境界に振幅1 Kのランダムな温位偏差を与えて対流を励起する。計算領域は水平50 km、鉛直20 km、格子間隔は200 mである。積分時間は30日である。

計算開始30日目には統計的平衡状態に達している。統計的平衡状態においては、冷却層において雲層が形成され、そこでは地表面付近を除き鉛直流の大きい対流は生じない。大気最下層から高度15 km付近まで雲層が形成され、雲密度は高度2 km付近で極大となる。1.0 m/s以上の大きさを持つ鉛直流は高度2 km以下にのみ見られ、その大きさは最大で約3.0 m/sである。高度2 km以下に見られる対流は、雲粒による引きずりの効果によって駆動されている。現実の火星での臨界飽和比は約1.35となることが実験的に知られており(Glandorf et al., 2002)、発表では臨界飽和比が1.35の場合についても報告する予定である。

キーワード: 大気主成分の凝結, CO₂ 氷雲, 雲対流モデル

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

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

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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.

キーワード: Mars, Planetary ice, Ice cap, Polar layered deposits, Modelling

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

火星北極冠にみられるスパイラルトラフの形成機構解明のためのアナログ実験：氷上に形成されるサイクリックステップ Analog experiments of formation of the spiral troughs on Mars' North Polar Layered Deposits: cyclic steps on ice

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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 Earth, 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.

キーワード: 火星北極冠, スパイラルトラフ, サイクリックステップ, 氷, 水路実験

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

MELOS Lander による電磁場観測 Electro-magnetic measurements by MELOS lander

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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 field 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 field, most of the targets will remain 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.

キーワード: 火星, ランダー, MELOS, 電磁場

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

現在の火星表層におけるダストおよび水の分布と挙動 Current distributions and behaviors of dust and water on the surface of Mars

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Dust and water are fundamentally important for the current status of both martian atmosphere and surface deformations. While the amount of airborne 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.

キーワード: 火星, ミーロス, ダスト, 水, 地質, 大気

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

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

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

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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.

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キーワード: Mars, Moon, rotation, shape, center of mass

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

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

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

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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

MELOS 生命探査提案：火星表面でのメタン酸化菌探査 MELOS LIFE SEARCH PROPOSAL: SEARCH FOR MICROBES ON THE MARS SURFACE WITH SPECIAL INTEREST IN METHANE-OXIDIZING BACTERIA

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近年の探査により、火星表層には、かつて大量の液体の水が存在していたこと、温暖湿潤な気候がある程度長期間保たれていたこと、そして火星は強い磁場を保持していたことが明らかにされた。これらを端的にまとめると、生命が生まれた頃の地球と極めて類似した環境を火星が持ち合わせていたという事に他ならない。こうした理由から、我々地球生命がどこから来て、どのような位置づけを持つかという究極的な問いに答えるために、火星は最も重要な研究対象であるといえる。

火星におけるメタンの発見と、地球におけるメタン酸化鉄還元細菌の発見 (Bealら 2009) から、我々は火星表面において現在もまだメタン酸化鉄還元細菌 (化学合成微生物の一種) が生存しているのではないかと推定するに至った。この菌はメタンを生成するメタン菌とは全く別の菌であり、表層付近で生育する可能性がある。火星の様々な環境は生命が十分に生存可能な環境である。また、紫外線は様々な物質によって吸収されるので、薄い火星土壌に覆われるだけで、火星表面も十分に生育可能な環境となる。従って、メタンと酸化鉄のような酸化型物質の両者がある場所であれば、数センチメートル程度の深さでも微生物は生存している可能性がある。こうした状況から、我々は火星地下深部を掘削する必要が無いという点を世界で初めて指摘するとともに、火星において生命を直接探査することを、現在の技術レベルでも十分に実現可能な手法を用いて、世界に先駆けて提案することとした。なお計画の特性から、火星表面における有機物や地質探査も同時に行うことができると考えている。

キーワード: MELOS, 火星, 生命探査, 蛍光顕微鏡, メタン酸化菌

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

地球生命進化を決めた最重要要素：初期海洋質量が3-5kmの厚さ Most essential factor of the habitable Earth: initial ocean volume 3-5km thick

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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.

SUBARU/IRCS 観測による火星メタン分布および生成領域の探索 Spatial distribution and source region of Martian CH₄ searched by the observation with SUBARU/IRCS

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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) (Geminala 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.

キーワード: 火星, 生命, メタン, 泥火山, 赤外線分光, すばる望遠鏡

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

SIMPLER: the Simultaneous Imaging Polarimeter onboard the MELOS Orbiter SIMPLER: the Simultaneous Imaging Polarimeter onboard the MELOS Orbiter

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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

惑星大気のミリ・テラヘルツ帯ヘテロダイン分光ための超伝導検出素子の開発 Development of superconducting detectors for mm/THz band heterodyne spectroscopy of planetary atmospheres

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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 ($f/df = \sim 10^{6-7}$). 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 superconducting 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 sputtering/deposition system, and performing test heterodyne measurements.

we will present these current status.

キーワード: 惑星大気, ヘテロダイン分光, ミリ波/テラヘルツ波, 超伝導検出素子, 地上電波望遠鏡

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

火星周回探査機搭載用サブミリ波サウンダ FIRE の観測装置の紹介 Introduction to the submillimeter receiver system for the atmospheric emission sounder FIRE/MELOS

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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.

キーワード: 火星, MELOS, サブミリ波サウンダ

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

火星周回探査機搭載用サブミリ波サウンダ FIRE の観測感度分析 Sensitivity study for the submillimeter-wave atmospheric emission sounder FIRE onboard a Martian orbiter

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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 (H₂O) profiles. The temperature and H₂O 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, H₂O, 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.

キーワード: 火星, MELOS, サブミリ波サウンダ

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

火星熱圏における解離再結合反応による加熱率

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

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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 a 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.

火星の火山地域のリソスフェア厚の再見積り Re-estimation of the lithospheric thickness of the volcanic areas on Mas

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火星の地殻について可能な密度範囲を再検討し、アドミッタンス計算に基づくリソスフェア厚への影響を定量的に調査した。使用したのは、MRO (Mars Reconnaissance Orbiter) が取得した火星の重力データから算出された `jgmro_110b2_anom_095.img` と MGS (Mars Global Surveyor) に搭載された MOLA (Mars Orbiter Laser Altimeter) が観測した火星の地形データ `megt90n000cb.img` である。共にグリッドデータとして提供されており、0.25-1 degrees の空間解像度を有する。今回は火星の火山地域に焦点を絞り、地殻密度を $2700-3100\text{kg/m}^3$ の範囲でパラメータとして振った場合に見積もられるリソスフェア厚の変動について報告し、過去の研究 (ex. McKenzie et al. [2002]) の結果と比較し、議論する。

キーワード: リソスフェア, 地殻, 火星, アドミッタンス, 重力, 地形

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

火星液体コアの大きさに対する実験的制約 Experimental constraints on the size of Martian liquid core

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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/cm³ 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 core Mars, Fe-Ni-S density, tomography, perovskite

亜臨界性による初期火星ダイナモの消滅 Cessation of early Martian dynamos due to subcriticality

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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 wider 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 extent of the subcritical regime makes it more likely that this effect may have played a role in the shutdown of the early Martian dynamo.

数値解析に基づく火星古海洋の堆積学的痕跡検出

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

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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.

キーワード: 火星, 衛星画像, 巨礫

Keywords: Mars, Satellite images, Boulder

最近における火星の火成活動によって形成された火山性コーン地形の分布 Global distribution of volcanic cones associated with recent Martian magmatism

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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.

キーワード: 火星, 火成活動, 火砕丘, スコリアコーン, ルートレスコーン

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

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

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

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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

火星マリネリス峡谷における地滑り地形の斜面解析 Slope analyses of massive landslides on Valles Marineris, Mars

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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 focused 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.

キーワード: 火星, ヴァリネリス峡谷, 地滑り, 安息角, 地形, データ解析

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