

月・固体惑星の科学：惑星探査の将来 構想に向けて

Sciences for the moon and solid planets toward
planning future planetary explorations

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固体惑星パネル

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The first stage panel for solid planets

目的 Aim

- 来る10年の我が国の惑星探査の目標となる第一級のサイエンスを抽出する

Survey and extraction of scientific issues of most importance for potential japanese planetary missions in the next decade

- 本パネルでは地球型惑星固体探査に関連するサイエンスを受け持つ

Our panel deals with science on the moon and solid planets

検討の経過 sequence of survey

- 2011 Jan 22 木星型惑星・氷衛星・系外惑星パネル分科会
- 2010 Dec 10 小天体パネル分科会
- 2010 Dec 07 地球型惑星固体パネル分科会 open specific forum about solid planets at University of Tokyo
- 2010 Nov 29 地球型惑星大気・磁気圏パネル分科会
- 2010 Nov 25 アストロバイオロジーパネル分科会
- 2010 Sep 10 「来る10年」第一段階の公開討論会 open general forum (supported by Center of Planetary Science, Kobe University)
- 2010 Aug 31 第一段階パネルへの意見書〆切 deadline of opinion from community members to the 1st stage panels
- 2010 May 26 第一段階のパネル検討紹介 briefing of preliminary survey in each 1st stage panels in JPGU meeting
- 2010 Mar 15 第11回惑星圏研究会にて「来る10年」活動紹介
- 2010 Mar 10 omlにて「来る10年」活動の紹介
- 2010 Jan 09 事務局, 第一段階のパネラー, 第二段階の委員候補者の決定
- 2009 Dec 18 運営委員会で「来る10年」活動が承認される
- 2009 Dec 13-14 将来惑星探査に関する意見交換会(於 支笏湖)にて企画提案 discussion and proposal of survey program

提案状況 Opinions for our panel

- パネル間では最多の 20 提案を得た

The most overall opinions among the 1st step panels

- 20 opinions

- 月 Moon=7, 火星 Mars=8, 複・その他 General or others=5

- 水星・金星に特化した提案なし、一般的課題のいくつかに包含

- No opinions specified for Mercury and Venus

- Some general opinion contain them

- 力点が科学視線・手法視点・融合視点など様々
Various styles

- Each focusing on scientific issues, methods and technique, or synergy among complementary methods and targets

意見マップ Opinion map

(Original titles are in Japanese)

- Major scientific issues on the origin and evolution approached by synergetic explorations

- Global mapping of major element distribution

- Isotopic constraints of lunar starting materials by sample return from the near and far sides

- Exploration of interior by seismometer network

- Sample return of crustal and mantle rocks from the Copernicus crater

- Crater chronology by returned sample from the Copernicus crater

- Sample return of earliest anorthosite crust

- * In-situ radio isotope chronology

- * In-situ elemental analysis of surface materials by LIBS

- * Study on carbon and chlorine bearing materials

- * Explorations of internal structures by geodetic measurements

- * Comparison of various evolutionary tracks among icy satellites and Earth

Aero explorations of Mars

“Small is beautiful missions”: connecting planetary physics, geology and biology by multi-site exploration with micro chemical analysis device

Atmosphere-surface interactions

- In-situ exploration of sedimentary rocks for the study of climate variability

- Study on solid Mars evolution from in-situ exploration of igneous rocks

Core size revealed from the observation of free oscillation excited by atmospheric disturbance

Internal structure deduced by observation of multiple lander network

- Exploration of internal structure and evolution

科学目標の整理

arrangement of scientific issues

- 第1段パネルの役割は科学目標の抽出
The primary role of 1st step panels is the extraction of top scientific questions for future exploration
- 提案の科学面に重点を置いて第一級の科学を抽出
Essential scientific issues are extracted from the opinions with some care for method and originality.
 - 「手法」面にも一定の配慮、「独創性」も重要な観点
 - パネラの見解も加味

固体惑星の科学的重要性

general scientific significance of solid planets

- 地球の起源と進化の理解に直結

direct contributions for understanding the origin and evolution of Earth

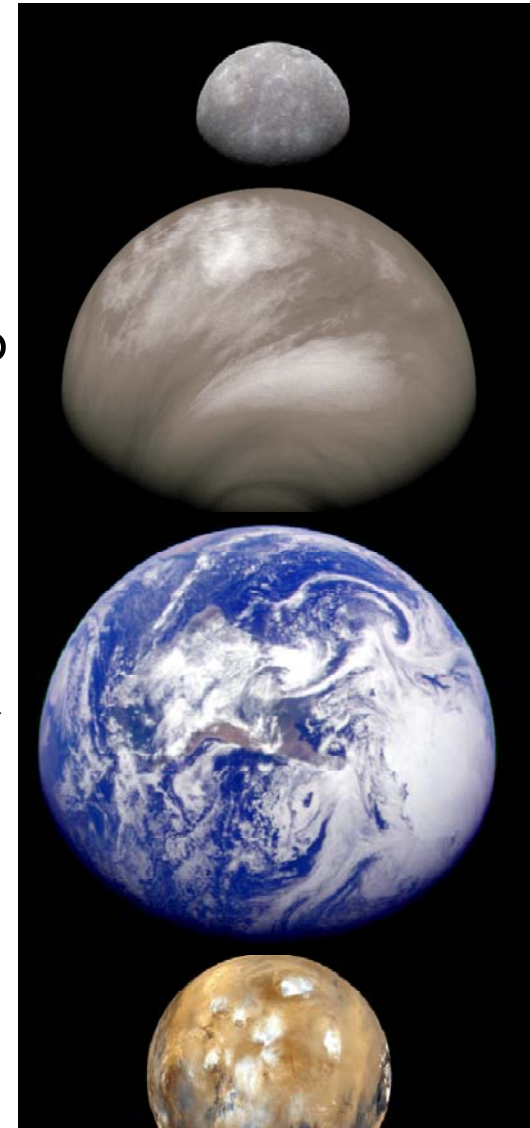
固体惑星＝地球にもっとも性質の近い天体.

その構造、現象、誕生から現在までの歴史を知ることによって惑星の形成と進化の過程を解明

Solid planets are the bodies most similar to our planet. Their structure, phenomena and geologic history provide us key information on the processes for their formation and evolution

地球や他の天体がそれぞれ個性を持った天体へと分岐した条件を明らかにできる

They tell us conditions and mechanisms that bifurcate diverged bodies



固体惑星の科学的重要性

general scientific significance of solid planets

- 太陽系全体の歴史の記録媒体

memory of the solar system history

月など初期に地質活動を終えた天体は、太陽系全体の歴史の良好な記録媒体

Smaller bodies with low intrinsic geologic activity
preserve records of early history of the solar system

惑星進化の外的諸要因がどのような変遷や進化を経てきたのかを解明する手掛かり

Telling us information on the external factors possibly
affecting the planetary evolution

第一級の科学パネル提案

panel recommendation of primary scientific issues

- 月惑星内部構造の解明
Internal structures of solid planets including the Moon
- 年代学・物質科学の展開による月惑星進化の解明
Evolution of solid planets as revealed from the development of advanced chronology and material sciences
- 固体部分と結合した表層環境の変動性の解明
Variability and evolution of surface environment coupled with solid planet

月惑星内部構造の解明

Internal structures of solid planets

- 構成物質と分化状態は、起源と進化の最も重要な手掛かり

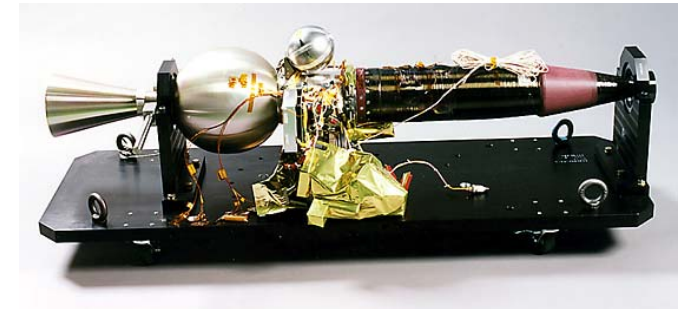
Constituent materials and internal structure are the key information for the origin and evolution of planets

- 月ですら地殻厚・コアサイズは不確定

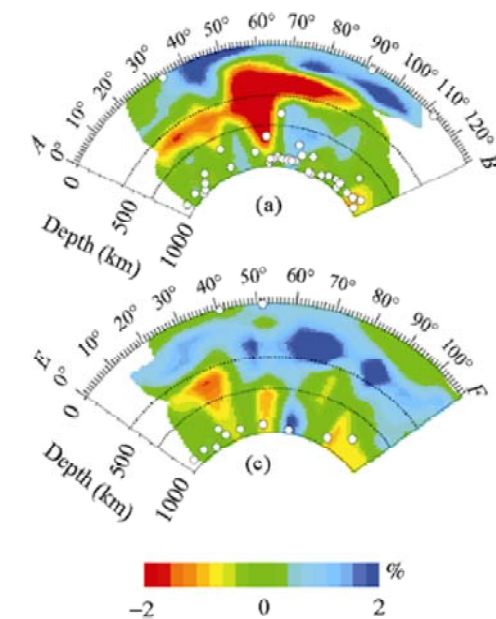
The crustal thickness and core size remain poorly constrained even for the Moon

- Lunar-A計画、ペネトレータ開発を通じ月惑星地震波探査技術、関連理論研究に優位性

Japan accumulates leading technology and theoretical basis for the seismic exploration of the Moon and solid planets through the Lunar-A program and penetrator development



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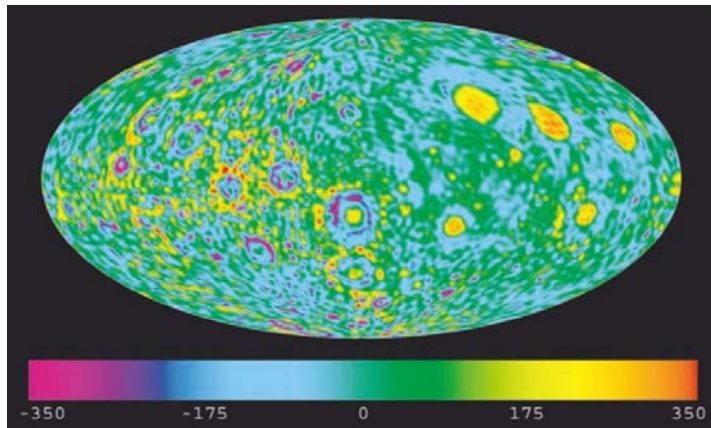


Attempted tomography using Apollo seismic data Zhao et al. (2008)

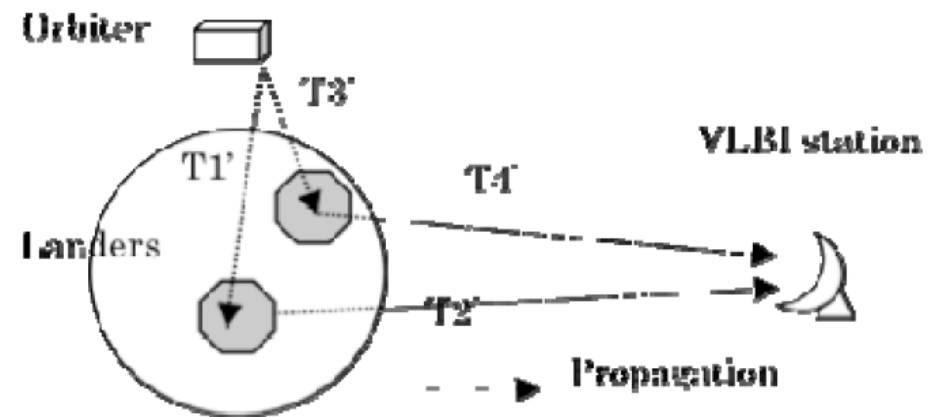
月惑星内部構造の解明

Internal structures of solid planets

- 測地・電磁気・熱流量計測と地表物質の組成同定を組み合わせることが内部構造制約に有用
Combination with geodetic, electro-magnetic and thermal measurements and surface material analysis is useful
- 月、地球型惑星、大型小惑星間の比較が望ましい
Comparison among the moon, terrestrial planets, and large asteroid is desirable



Lunar gravity map from Kaguya data
Namiki et al. (2009)



VLBI using an orbiter and two landers observes precisely the spin rate variability
Sasaki et al (2010)

年代学・物質科学の展開による月惑星進化の解明

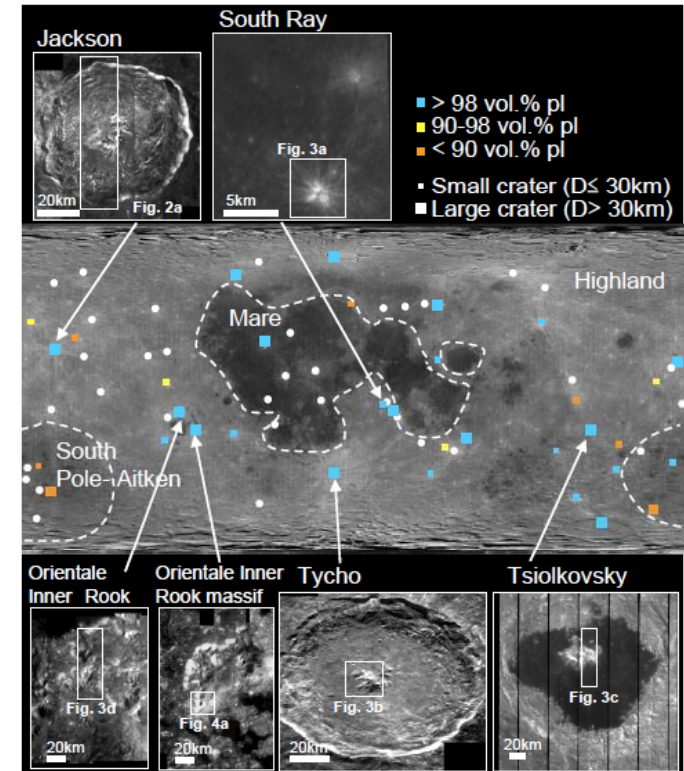
Evolution of solid planets as revealed from the development of advanced chronology and material sciences

- リモートセンシング探査が充実. 相補的な方向性が求められる.

A large number of remote sensing missions have accumulated high quality data and images. Complementary approaches are desirable.

- クレータ年代目盛とリモートセンシングデータによる組成決定に不確定性

There remain uncertainties in crater chronology and material compositions deduced from remote sensing data.



Discovery of purest anorthosite
From Kaguya data
Ohtake et al (2010)

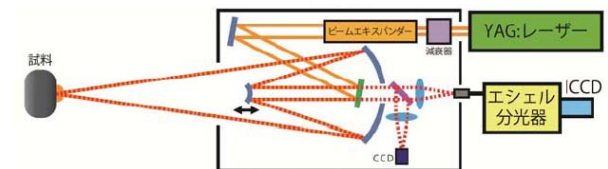
年代学・物質科学の展開による月惑星進化の解明

Evolution of solid planets as revealed from the development of advanced chronology and material sciences

- **新たな地点の試料分析による月クレータ年代学の精度向上**
太陽系全体の惑星軌道進化史のよりよい制約に
Improvement of the crater chronology by sampling and analysis of rocks from new sites.
- **産出状況の明らかな試料の直接分析**
地質構造と関連づけた解釈
Direct analysis of samples with identifying geologic context.
- **大気成分・同位体組成の直接決定による大気の起源と進化の制約**
Direct analysis of atmospheric compositions to constrain the atmospheric origin and evolution



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Optics of laser induced breakdown spectroscopy
Namiki et al (2010)

固体惑星と結合した表層環境の変動性の解明

Variability and evolution of surface environment coupled with solid planet

- 大気と固体惑星は力学的、物質科学的に相互作用

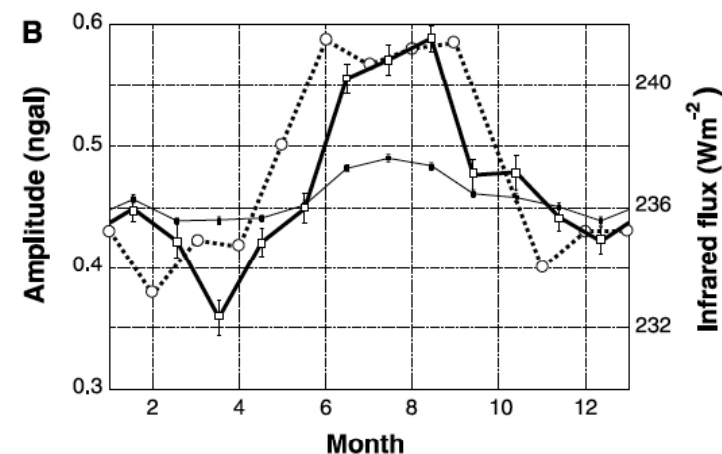
Atmosphere and solid planet interact dynamically and chemically

- 短期的には固体惑星の自転、重力場変動や微小長周期地震動を励起

In short time scale, it induces variation of planetary spin and gravity fields and long period seismic motion with small but detectable amplitudes

- 内部構造を決定する観測手法によりモニタリング可能

These may be monitored by applying technique observing internal structure



Correlation between the Earth's background free oscillation and atmospheric radiation
Nishida et al. (2000)

固体惑星と結合した表層環境の変動性の解明

Variability and evolution of surface environment coupled with solid planet

- 長期的には表層環境の変動・進化をもたらす

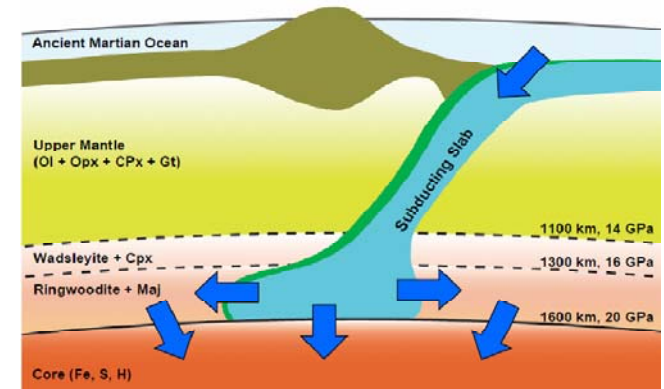
In long time scale, the coupling may cause change of surface environment.

- 固体惑星の揮発性物質リザーバーサイズ、表層環境史、脱ガス気体成分などの制約が重要

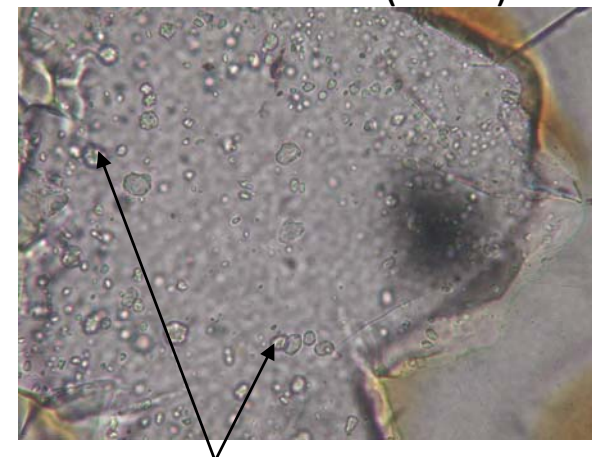
Constraining of volatile reservoir size in solid planets, history of surface environment, and degassing flux and its compositions is important.

- 大気を持たない天体のレゴリスの物質科学的分析からも、隕石重爆撃、太陽風組成、太陽活動履歴などについて制約可能

External factors affecting the surface environment, such as heavy bombardment, solar wind, and historic solar activity, may be constrained by analysis of regolith samples from airless bodies.



Transport of water into deep Mars
Shibasaki et al. (2009)



Coesite grains in a lunar meteorite, possible probe of bombardment history
Ohtani et al (2010)

最後に

- 意見募集中 (6月末まで)

Our survey is ongoing (completed in June)

- 詳しくは惑星科学会HPをご覧ください

https://www.wakusei.jp/~decade_sec/wiki/open/