Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

BAO01-01 会場:502 時間:4 月 28 日 09:00-09:15

太陽型星でのスーパーフレア
Superflares on Solar-Type Stars

柴山 拓也 [1*] ; 前原 裕之 [2] ; 野津 湧太 [3] ; 野津 翔太 [3] ; 本田 敏志 [4] ; 野上 大作 [3] ; 柴田 一成 [3]
SHIBAYAMA, Takuya[1*] ; MAEHARA, Hiroyuki[2] ; NOTSU, Yuta[3] ; NOTSU, Shota[3] ; HONDA, Satoshi[4] ; NOGAMI, Daisaku[3] ; SHIBATA, Kazunari[3]

[1] 名古屋大学, [2] 東京大学, [3] 京都大学, [4] 兵庫県立大学
[1]Nagoya University, [2]University of Tokyo, [3]Kyoto University, [4]University of Hyogo

Stellar flares emit harmful UV and high-energy particles such as protons. Although the atmosphere protects the surface of the planets, certain amount of UV penetrates the atmosphere and high-energy particles reach the ground as secondary radiation. These radiations are thought to affect habitability and evolution of life.

High precision photometry of Kepler spacecraft enables us to detect superflares on G-type dwarfs. By extending Maehara et al. (2012, Nature), we found 1547 superflares on 279 G-type dwarfs detected from light curves of 500 days (Shibayama et al., 2013, ApJS). In the case of the Sun-like stars (with surface temperature 5600 - 6000 K and slowly rotating with a period longer than 10 days), the frequency of superflares with energy of 10^{34} - 10^{35} erg (100 - 1,000 times larger than the largest solar flare) is once in 800 - 5000 years. No hot Jupiters were found in these superflare stars. These superflare stars often show quasi-periodic brightness variation, which might be evidence of the large star spot. Rotational period can be estimated from the brightness variation period. It is interesting that superflares are detected on slowly rotating stars (P $>$10 days) like the Sun. Using these data, we studied the statistical properties of superflares. We compare the flare frequency distribution of the superflare and solar flare, and study the similarity of them. We also found that some G-type dwarfs show very high activity and exhibit superflares once in ~ 10 days. In the case of Sun-like stars, the most active stars show one superflare in ~ 100 days.

キーワード: 恒星フレア, 太陽フレア, ハビタビリティ, 進化
Keywords: Stellar flare, Solar flare, Habitability, Evolution

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グリシン前駆体、メチレンイミンの多天体探査
Survey Observations of A Glycine Precursor, Methylenimine (CH2NH)

鈴木 大輝 [1*] ; 大石 雅寿 [2] ; 廣田 朋也 [2] ; 斎藤 正雄 [2]
SUZUKI, Taiki[1*] ; OHISHI, Masatoshi[2] ; HIROTA, Tomoya[2] ; SAITO, Masao[2]

[1] 総合研究大学院大学物理科学研究科天文科学専攻, [2] 国立天文台
[1]Department of Astronomy, the Graduate University for Advanced Studies (SOKENDAI), [2]National Astronomical Observatory of Japan

It is widely thought that prebiotic chemical evolution from small to large and complex molecules would have resulted in the Origin of Life. The interstellar medium (ISM), where more than 170 molecules ranging from simple linear molecules to COMs were detected, show chemically rich environment. Ehrenfreund et al. (2002) argued that exogenous delivery of COMs to the early Earth by comets and/or asteroids could be more than their terrestrial formation by two orders of magnitude; molecules delivered from the Universe might have played an important role in early Earth chemistry. From this point of view, many observations were conducted to search for prebiotic molecules in the ISM, which might turn into the " Seeds of Life " when delivered to planetary surface. Especially, great attention was paid to amino acids, essential building blocks of terrestrial life; many surveys were made unsuccessfully to search for the simplest amino acid, glycine (NH_2CH_2COOH), towards Sagittarius B2 and other high-mass star forming regions (e.g., Brown et al. 1979; Snyder et al. 1983; Combes et al. 1996, ...).

In these days, the Atacama Large Millimeter/submillimeter Array (ALMA) is expected to break through such difficulties associated with glycine survey. Garrod (2013) used her chemical reaction network simulation and argued the possibility in detecting glycine with very high spatial resolution (~0.1 ″) and the collecting power of ALMA. It would be important to know which are potential glycine-rich sources for future surveys. However, the chemical evolution of N-bearing molecules, including glycine, is poorly known. We would need to better understand formation mechanisms of N-bearing COMs including amino acids and to have carefully selected good candidate sources for amino acids before conducting searches for amino acids by ALMA.

Although the chemical evolution of interstellar N-bearing COMs is poorly known, methylamine (CH_3NH_2) has been proposed as a precursor to glycine. Theoretical and laboratory studies have demonstrated that glycine is formed on icy grain surface from CH_3NH_2 and CO_2 under UV irradiation (Holtom et al. 2005). It is suggested that CH_3NH_2 can be formed from abundant species, CH_4 and NH_3, on icy dust surface (Kim & Kaiser 2011). Further methyleneimine (CH_2NH) would be related to CH_3NH_2. Another possible route to form these species is hydrogenation to HCN on the dust surface (Dickens et al. 1997; Theule et al. 2011).

However, a source number of such precursor molecules is very limited. In order to increase the number of CH_2NH sources and to better understand formation paths to CH_2NH, we conducted survey observations of CH_2NH, with the NRO 45 m telescope and the SMT telescope towards 11 high-mass and three low-mass star-forming regions. As a result, CH_2NH was detected in eight sources, including four new sources. The estimated column densities were roughly 10^{14}-10^{15}, 10^{15}-10^{16}, and 10^{16}-10^{17} cm^{-2}, respectively, for extended, 10 ″ , and 2 ″ sources. G10.47+0.03 and Orion KL are found to be especially CH_2NH-rich sources. We used chemical reaction network simulations to investigate formation process of CH_2NH in the ISM. Under the dark cloud condition, the simulated CH_2NH abundance in the gas phase is more than 10 times lower than our observations even if we conservatively estimate the CH_2NH abundance with an extended source. On the other hand, if we include hydrogenation reaction to HCN in our model, the CH_2NH abundance increased about by two orders of magnitude, enabling us to reconcile the observed abundance of CH_2NH. We also showed that this reaction is dominant in the early, low temperature phase of cloud evolution.

キーワード: 生命起源, 化学進化, 星間空間, グリシン
Keywords: Origin of Life, Chemical Evolution, Interstellar Medium, Glycine

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星間での有機物生成・変成と地球への伝搬：地上実験と宇宙実験による検証
Formation, alteration and delivery of interstellar organics: Verification with experiments on ground and in space

小林 憲正 [1*] ; 柴田 裕実 [2] ; 田村 元秀 [3] ; 高山 健 [4] ; 金子 竹男 [5] ; 福田 一志 [6] ; 小栗 慶之 [6] ; 吉田 聡 [7] ; 神田 一浩 [8] ; 山岸 明彦 [9] ; たんぽぽ ワーキンググループ [10]
KOBAYASHI, Kensei[1*] ; SHIBATA, Hiromi[2] ; TAMURA, Motohide[3] ; TAKAYAMA, Ken[4] ; KANEKO, Takeo[5] ; FUKUDA, Hitoshi[6] ; OGURI, Yoshiyuki[6] ; YOSHIDA, Satoshi[7] ; KANDA, Kazuhiro[8] ; YAMAGISHI, Akihiko[9] ; TANPOPO, Working group[10]

[1] 横浜国立大学・自然科学研究機構, [2] 大阪大学, [3] 東京大学・国立天文台・自然科学研究機構, [4] 高エネルギー加速器研究機構, [5] 横浜国立大学大学院工学研究院, [6] 東京工業大学大学院理工学研究科, [7] 放射線医学総合研究所, [8] 兵庫県立大学, [9] 東京薬科大学・自然科学機構, [10]JAXA 宇宙科学研究所
[1]Yokohama National University, NINS, [2]Osaka University, [3]University of Tokyo, NAOJ, NINS, [4]High Energy Accelerator Research Organization, [5]Faculty of Engineering, Yokohama National University, [6]Graduate School of Science and Engineering, Tokyo Institute of Technology, [7]National Institute of Radiological Sciences, [8]University of Hyogo, [9]Tokyo University of Pharmacy and Life Science, NINS, [10]JAXA/ISAS

星間での宇宙線による複雑有機物の生成，太陽系での変成，惑星間塵による地球への伝搬を含む生命起源のシナリオを構築した。その検証のための加速器実験，および宇宙実験（たんぽぽ計画）について説明する。

キーワード: 生命の起源, 星間有機物, 宇宙線, 惑星間塵, たんぽぽ計画, 粒子線照射
Keywords: origins of life, interstellar organic compounds, cosmic rays, interplanetary dust particles, Tanpopo Mission, particles irradiation

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Polymerization of methionine: Ignition of sulfur metabolism?
Polymerization of methionine: Ignition of sulfur metabolism?

掛川 武 [1*]
KAKEGAWA, Takeshi[1*]

[1] 東北大学大学院理学研究科地学専攻
[1]Graduate School of Science, Tohoku University

Methionine, sulfur-bearing amino acid, is one of protein-forming 20 amino acids. On the other hand, peptide formation using methionine is known to be difficult, because of large thermal stability of methionine. Incorporation of methionine into peptide has importance to form metal-sulfur-cluster in protein or other biologically important molecules, such as taurine. In order to overcome difficulties to make methionine-bearing peptide, new series of experiments were performed in the present study. Experiments were performed at 175 C and 150 MPa, using various mixtures. Methionine-trimers, which were not formed by previous investigators, were produced in the present study. Surprisingly a part of methionine was converted into glycine and then glycine-methionine peptide was newly formed. Those results demonstrated that high T and P conditions were suitable for not only methionine-peptide formation but also making multi-component peptide. Sulfur isotope compositions were determined on run products of the present study. Run products were enriched or depleted in 32S compared to starting materials. Hydrogen sulfides were preferentially released from methionine for the 32S-depleted samples. The 32S-enriched samples are explained by loss of sulfate from methionine, although oxidants of methionine-sulfur are still unclear. Modern living organisms metabolically produce sulfide and sulfate from methionine and cysteine. Such metabolic path is similar to the abiological production of sulfide and sulfate in the present study. This may imply that course of sulfur metabolism was most likely established early in the prebiotic age when methionine was incorporated in prebiotic protein.

キーワード: prebiotic, methionine, peptide, sulfur
Keywords: prebiotic, methionine, peptide, sulfur

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生命を生み出す地球外海洋を作る
Formation of extraterrestrial oceans: Cradles of life

佐々木 晶[1*] ; 木村 淳[2] ; 近藤 忠[2] ; 松本 晃治[3] ; 千秋 博紀[4] ; 関根 康人[5] ; 渋谷 岳造[6] ; 久保 友明[7] ; 並木 則行[4] ; 堀 安範[3] ; 鎌田 俊一[8]
SASAKI, Sho[1*] ; KIMURA, Jun[2] ; KONDO, Tadashi[2] ; MATSUMOTO, Koji[3] ; SENSHU, Hiroki[4] ; SEKINE, Yasuhito[5] ; SHIBUYA, Takazo[6] ; KUBO, Tomoaki[7] ; NAMIKI, Noriyuki[4] ; HORI, Yasunori[3] ; KAMATA, Shunichi[8]

[1] 大阪大学大学院理学研究科宇宙地球科学専攻, [2] 東京工業大学地球生命研究所, [3] 国立天文台, [4] 千葉工業大学惑星探査研究センター, [5] 東京大学大学院新領域創成科学研究科, [6] 海洋研究開発機構, [7] 九州大学大学院理学研究院地球惑星科学部門, [8] 北海道大学理学研究院
[1]Department of Earth and Space Sciences, Osaka University, [2]ELSI, Tokyo Institute of Technology, [3]National Astronomical Observatory, [4]PERC, Chiba Institute of Technology, [5]The University of Tokyo, [6]Japan Agency for Marine-Earth Science and Technology, [7]Department of Earth and Planetary Sciences, Kyushu University, [8]Hokkaido University

科学研究費に提案中のプロジェクト「太陽系の海と生命たち」（代表：山岸明彦氏）の 1 グループとして、太陽系形成の新しい描像に沿った衛星起源・進化の理論研究、氷高圧物性実験、岩石水相互作用研究により、巨大惑星の氷衛星の起源と形成過程、地下海形成過程および普遍性の解明を目指している。

雪線 (スノーライン) の外側で集積した木星型惑星周囲には氷に富む衛星系が存在する。軌道共鳴状態に入ると潮汐摩擦で、地下海が生成・維持される。太陽から遠ざかると表面温度は下がるが、NH_3, CH_4, CO など融点を下げる成分は増える。水岩石相互作用により生成される塩類は、生命材料となるとともに 氷の融点を下げる。いわゆるハビタブルゾーン（液体の水が安定に存在する領域）は、氷天体地下圏を想定すると、大きく広がることになる。

多様なパラメーターに基づく地下海の存在条件を明らかにするため、 (1) 氷衛星の材料・起源・進化の理論研究、(2) 高圧下の氷物性と融解条件の解明、(3) 岩石水相互作用と塩類の供給の解明、(4) 氷衛星地下海の検出精度の向上の研究を行うことを計画している。とくに、JUICE ミッションのガニメデ観測を想定して、本研究から地下海検出のために必要な測地・重力精度を明らかにする。塩類を含む海の進化、塩類の分光測定、地下海のエネルギー環境、有機物については別班と協力して、生命を育む地下環境を明らかにする。

太陽系外惑星では、主星の近くまで移動した Hot Jupiter と呼ばれる天体が多く発見されている。衛星系が形成された後に、巨大惑星の軌道が内側に移動すると、氷衛星が水衛星となり、最後には散逸して岩石衛星になると考えられる。近年、太陽系の木星、土星は形成後に軌道が現在よりもかなり内側 (1-2AU) まで移動したシナリオが考えられている。木星の衛星カリストの CO_2 の存在や未分化内部構造は、木星の軌道進化を制約づけるか、木星の衛星系の形成時期がかなり後であることを示唆することになる。

キーワード: 氷衛星, 生命存在条件, 地下海, ハビタブルゾーン, 木星型惑星, 惑星系の起源
Keywords: icy satellites, habitability, interior ocean, habitable zone, gas giant planets, origin of planetary systems

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国際宇宙ステーション曝露部での微粒子捕集、微生物有機物曝露実験：たんぽぽ
Tanpopo: Astrobiology Exposure and Micrometeoroid Capture Experiments - Experiments at the Exposure Facility of ISS-JEM

山岸 明彦[1*] ; 横堀 伸一[1] ; 矢野 創[2] ; 橋本 博文[2] ; 今井 栄一[3] ; 田端 誠[2] ; 河合 秀幸[4] ; 薮田 ひかる[5] ; 東出 真澄[6] ; 小林 憲正[7] ; 三田 肇[8]
YAMAGISHI, Akihiko[1*] ; YOKOBORI, Shin-ichi[1] ; YANO, Hajime[2] ; HASHIMOTO, Hirofumi[2] ; IMAI, Eiichi[3] ; TABATA, Makoto[2] ; KAWAI, Hideyuki[4] ; YABUTA, Hikaru[5] ; HIGASHIDE, Masumi[6] ; KOBAYASHI, Kensei[7] ; MITA, Hajime[8]

[1] 東京薬科大学生命科学部, [2]JAXA 宇宙科学研究所, [3] 長岡技術科学大学生物系, [4] 千葉大学理学研究科, [5] 大阪大学大学院理学研究科, [6]JAXA 研究開発本部, [7] 横浜国立大学, [8] 福岡工業大学工学部
[1]Tokyo University of Pharmacy and Life Sciences, [2]ISAS/JAXA, [3]Nagaoka University of Technology, [4]Chiba University, [5]Osaka University, [6]Innovative Technology Research Center, Japan Aerospace Exploration Agency, [7]Yokohama National University, [8]ukuoka Institute of Technoology

Tanpopo, a dandelion in Japanese, is a plant species whose seeds with floss are spread by wind. We propose this mission to examine possible interplanetary migration of microbes, and organic compounds at the Exposure Facility of Japan Experimental Module (JEM: KIBO) of the International Space Station (ISS). The Tanpopo mission consists of six subthemes: Capture of microbes in space (Subtheme 1), exposure of microbes in space (Subtheme 2), analysis of organic compounds in interplanetary dust (Subtheme 3), exposure of organic compounds in space (Subtheme 4), measurement of space debris at the ISS orbit (Subtheme 5), and evaluation of ultra low-density aerogel developed for the Tanpopo mission (Subtheme 6). 'Exposure Panel' for exposure of microbes and organic materials and 'Capture Panels' for capturing micro particles with aerogel will be launched. The panels will be placed on the Exposed Experiment Handrail Attachment Mechanism (ExHAM) in the ISS. The ExHAM with the panels will be placed on the Exposure Facility of KIBO (JEM) with the Japanese robotic arms through the airlock of KIBO. The panels will be exposed for more than one year and will be retrieved and returned to the ground for the analyses.

キーワード: パンスペルミア仮説, 微生物, 有機物, エアロゲル, 宇宙曝露実験
Keywords: Panspermia hypothsis, Microbes, Organic compounds, Aerogel, Space exposure experiments

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Rock Magnetic Constraints on the origin of putative biological magnetite in the Martian ALH84001 Carbonates

Rock Magnetic Constraints on the origin of putative biological magnetite in the Martian ALH84001 Carbonates

KIRSCHVINK, Joseph[1*] ; KOBAYASHI, Atsuko[2] ; BUZ, Jennifer[1] ; THOMAS-KEPRTA, Kathie[3] ; CLEMETT, Simon[3]
KIRSCHVINK, Joseph[1*] ; KOBAYASHI, Atsuko[2] ; BUZ, Jennifer[1] ; THOMAS-KEPRTA, Kathie[3] ; CLEMETT, Simon[3]

[1]California Institute of Technology, Pasadena USA, [2]Earth/Life Science Institute, Tokyo Tech., [3]ESCG at NASA/Johnson Space Center, Houston TX
[1]California Institute of Technology, Pasadena USA, [2]Earth/Life Science Institute, Tokyo Tech., [3]ESCG at NASA/Johnson Space Center, Houston TX

McKay et al. (1996) discussed 4 lines of evidence that were consistent with the possible presence of ancient life on Mars. Although none of these have been falsified, the one that has triggered the most intense debate concerns the claim that some of the fine-grained magnetite crystals embedded in small carbonate deposits might have been formed by the magnetotactic bacteria. These magnetite particles, when examined by high-resolution transmission electron microscopy, are indistinguishable from particles only produced by magnetotactic bacteria on Earth (Thomas-Keprta et al., 2001). Unfortunately, the magnetic and microscopic analyses done to date do not allow us to provide a direct statistical test of the probability that these particles are of biological origin, vs. the hypothesis they form from high-temperature decomposition of siderite (FeCO3).

In the past decade, developments in superconducting magnetometry and electron microscopy now provide new experimental approaches that can be applied to this problem. First, the new Ultra-High Resolution Scanning Magnetic Microscopes (UHRSMMs) can detect magnetic moments 3 to 4 orders of magnitude below the sensitivity of the best superconducting rock magnetometers, and robust dipole-fitting routines allow the 3-D vector magnetic moment of tiny particles to be resolved quantitatively. We have shown recently that individual fragments of the famous ALH84001 carbonate blebs can be imaged clearly using this technique, opening the possibility of experimental tests that should distinguish low-temperature (biological) from high-temperature (thermal decomposition) magnetite. Magnetite produced by thermal decomposition of carbonate during shock heating should carry a relatively strong Thermo-Remanent Magnetization (TRM), whereas biological magnetite trapped during carbonate growth should have a much weaker detrital magnetization (DRM). Fuller et al. (1988) reported a simple technique that compares the relative intensities of the Natural Remanent Magnetizations (NRMs) to Isothermal and Anhysteretic magnetizations (IRMs and ARMs) that can easily distinguish TRMs from DRMs; this new sensitivity now be applied to these particles. Second, because the magnetotactic bacteria use genetic control to manufacture their magnetite crystals, particles within the same cell are of very similar size and shape. When these cells die and leave their magnetite crystals in the sedimentary record as magnetofossils, they produce clumps of similarly-sized crystals because they stick together magnetically with very strong force (Kobayashi et al., 2006). Sediment transport and removal processes cannot disaggregate them, but they do get scrambled together during extraction and high-resolution TEM studies. We therefore need to do very high-resolution studies that can demonstrate the position of these crystals within the carbonate matrix of the ALH 84001 carbonate precipitates. We propose to use the new focused ion-beam (FIB) milling techniques available at the Earth-Life Science Institute of TiTech to make 3-dimensional reconstructions, at a 5 to 10 nanometer scale, of rectangular chunks of the ALH84001 carbonate. At this resolution, the putative magnetosomes will be represented by up to 500 voxel elements, each with definitive elemental composition. We should be able to determine whether clusters of particles within these carbonates are of similar size and shape, as expected from collapsed magnetosome chains. It will then be very simple to do statistical tests to determine whether these clumps are non-random assemblages sampled from the background crystal size distribution. The debate about life on Mars may rise again!

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キーワード: Martian Magnetofossils, Rock Magnetism, Panspermia, Carbonate
Keywords: Martian Magnetofossils, Rock Magnetism, Panspermia, Carbonate

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Cu-Zn ores in 2.7 Ga komatiite-basalt assemblages in Abitibi Greenstone Belt, Canada, and their associations to microbs

Cu-Zn ores in 2.7 Ga komatiite-basalt assemblages in Abitibi Greenstone Belt, Canada, and their associations to microbs

掛川 武 [1*]
KAKEGAWA, Takeshi[1*]

[1] 東北大学大学院理学研究科
[1]Graduate School of Science, Tohoku University

Archean greenstone belts are hosting many massive sulfide ores. In particular, komatiite-basalt sequences are hosting Ni-Cu ores, which are mostly considered as a magmatic in origin. Some Ni-Cu ores are associated with serpentinization near seafloor. Such serpentinization may have been important for early life as hydrogen donors with alkaline fluids. Cu-Zn-Pb ores are also reported from the same komatiite-basalt sequences, although the origin of these ores are still uncertain. One representative 2.7 Ga komatiite-basalt sequence appears in the Munro area of the Abitibi Greenstone Belt. In order to understand the origin of Cu-Zn-Pb ores, mineralogical and geochemical studies are performed on ores at Munro area. Sulfide ores are essentially developed in black shale zones, and some ores are disseminated in altered volcanic rocks. Chalcopyrite, sphalerite, pyrrhotite are major minerals associated with minor galena, electrum, pentlandite, etc. Sulfur isotope compositions of those sulfides are ranging are not magmatic values. Some ores are rich in Se and As. Host volcanic rocks are extensively hydrated (followed by metamorphism) forming tremolite, chlorite and talc. Those features are similar to the modern submarine hydrothermal deposits, rather than magmatic ore deposits. Therefore, Cu-Zn-Pb ores in komatiite-basalt sequences were formed by black smoker type submarine hydrothermal activities. Carbon isotope analyses of organic matter in ore-associated sediments suggest that methanogens were active when komatiite became serpentinite, followed by submarine hydrothermal activities.

キーワード: Komatiite, ore, submarine, Abitibi, microbe
Keywords: Komatiite, ore, submarine, Abitibi, microbe

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地球および地球外深海熱水環境における生命生態系
Microbial community development in deep-sea hydrothermal vents in the Earth, and the Enceladus

高井 研 [1*] ; 渋谷 岳造 [1] ; 関根 康人 [2] ; ラッセル マイケル [3]
TAKAI, Ken[1*] ; SHIBUYA, Takazo[1] ; SEKINE, Yasuhito[2] ; RUSSELL, M. J.[3]

[1] 独立行政法人海洋研究開発機構, [2] 東京大学大学院新領域創成科学研究科, [3] カリフォルニア工科大学ジェット推進研究所
[1]Japan Agency for Marine-Earth Science & Technology, [2]Department of Complexity Science & Engineering, University of Tokyo, [3]Jet Propulsion Laboratory, California Institute of Technology

Over the past 35 years, researchers have explored seafloor deep-sea hydrothermal vent environments around the globe and studied a number of microbial ecosystems. Bioinformatics and interdisciplinary geochemistry-microbiology approaches have provided new ideas on the diversity and community composition of microbial life living in deep-sea vents. In particular, recent investigations have revealed that the community structure and productivity of chemolithotrophic microbial communities in the deep-sea hydrothermal environments are controlled primarily by variations in the geochemical composition of hydrothermal fluids. This was originally predicted by a thermodynamic calculation of energy yield potential of various chemolithotrophic metabolisms in a simulated hydrothermal mixing zone. The prediction has been finally justified by the relatively quantitative geomicrobiological characterizations in various deep-sea hydrothermal vent environments all over the world. Thus, there should be a possible principle that the thermodynamic estimation of chemolithotrophic energy yield potentials could predict the realistic chemolithotrophic living community in any of the deep-sea hydrothermal vent environments in this planet. In 2005, a spacecraft Cassini discovered a water vapour jet plume from the sole pole area of the Saturnian moon Enceladus. The chemical composition analyses of Cassini's mass spectrometer strongly suggested that the Enceladus could host certain extent of extraterrestrial ocean beneath the surface ice sheet and possible ocean-rock hydrothermal systems. An experimental study simulating the reaction between chondritic material and alkaline seawater reveals that the formation of silica nanoparticles requires hydrothermal reaction at high temperatures. Based on these findings, we attempt to built a model of possible hydrothermal fluid-rock reactions and bioavailable energy composition in the mixing zones between the hydrothermal fluid and the seawater in the Enceladus subsurface ocean. The physical and chemical condition of the extraterrestrial ocean environments points that the abundant bioavailable energy is obtained maximally from redox reactions based on CO_2 and H_2 but not from with other electron accepters such as sulfate and nitrate. In the low-temperature zones, the available energy of the Enceladus methanogenesis and acetogenesis is higher than those in any Earth's environment where the methanogens sustain the whole microbial ecosystem. Our model strongly suggests that the abundant living ecosystem sustained by hydrogenotrophic methanogensis and acetogenesis using planetary inorganic energy sources should be present in the Enceladus hydrothermal vent systems and the ocean.

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光合成における光吸収とエネルギー伝達：バイオマーカーの拡張に向けて
Light absorption and energy transfer in photosynthesis: Toward extending our current biosignatures

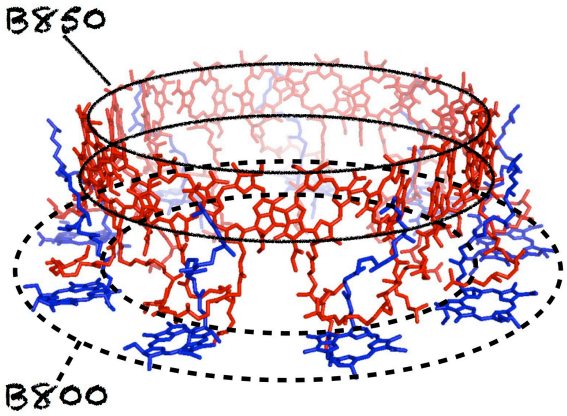
小松 勇 [1*] ; 梅村 雅之 [1] ; 庄司 光男 [1] ; 栢沼 愛 [1] ; 矢花 一浩 [1] ; 白石 賢二 [2]
KOMATSU, Yu[1*] ; UMEMURA, Masayuki[1] ; SHOJI, Mitsuo[1] ; KAYANUMA, Megumi[1] ; YABANA, Kazuhiro[1] ; SHIRAISHI, Kenji[2]

[1] 筑波大学, [2] 名古屋大学
[1]University of Tsukuba, [2]Nagoya University

In the recent success in detecting for extrasolar planets, several habitable planets, which can sustain liquid water, have already been discovered. From reflection spectra on exoplanets, what and how to detect signs of life, biosignatures, have been controversial (Kiang et al. 2007). One of proposed biosignatures is vegetation red edge (VRE), which is observed from reflectance spectra on the Earth. VRE is identified as a sharp contrast in about 700 - 750 nm due to the absorption in visible region by photosynthetic pigments like chlorophylls and the reflection in NIR region. However, VRE is an effective as biosignature only if exovegetation shows the same spectral feature to that on the Earth (Seager et al. 2005). Therefore, the criterion as biosignature needs to be extended when the primary stars are totally different. Because in future missions searching for a second earth, the M type stars (cooler than Sun) will be the main targets, as the first step, we focused on the fundamental properties of purple bacteria which absorbs longer wavelength radiation (1025 nm).

We investigated light absorptions and excitation energy transfers (EETs) based on quantum dynamics simulations for light harvesting complexes (LHCs), which contain array of photosynthetic pigments. After light reaches in LHCs, effective EET is accomplished by corporative electronic excitation of the pigments. We used theoretical models for LHCs in purple bacteria (LH2s). LH2 is made of 2 rings: inner ring (B850) and the outer (B800), as shown in Figure. In our model, a dipole-dipole approximation was used for the electronic excitations. The low-lying electronic excited states of a LH2 were computed by using transition dipole moment of first excited state of each pigment calculated at time-dependent density functional theory. Corresponding to the light absorption process, the oscillator strength in the system could be computed. The oscillator strength of one LH2 was in a good agreement with the experimental value. Subsequently, quantum dynamics simulations were performed by Liouville equation to examine the EET process. In this model, the densities relaxed according to energy gradient. This treatment corresponded with the EET process. The relaxation parameters were determined based on the energy transfer time from B800 to B850 (0.8 ps). The calculated transfer time between two LH2s was determined to 2.72 - 3.67 ps in good agreement with the experiment values (2.0 - 10.0 ps). In order to deal with more realistic system, we calculated at a macro structural model. The calculated systems were composed of 7 LH2s and 19 LH2s, where LH2s were aligned in triangle lattice. As the system size increases, the oscillator strength shifted longer and the transfer velocity became faster. In photosynthesis, collected energies are efficiently transferred to lower energy sites where redox reactions take place, very efficiently by EET. When two pigments in central LH2 in the system were exchanged to pigments absorbed longer wavelength radiation (850 nm to 890 nm), the transfer velocities became faster. Moreover, in order to examine for what environments the absorption spectra of purple bacteria were optimized, the absorption efficiency was calculated from blackbody spectra expected in typical extrasolar planets. As a result, the absorption efficiency was maximum at the emission spectrum of a black body at around 200 K. Furthermore, the Light absorptions and EETs in purple bacteria, cyanobacteria and plants will be examined by using our methodology.

Keywords: biosignatures, extrasolar planets, photosynthesis, quantum chemical calculation, light harvesting, purple bacteria



Japan Geoscience Union Meeting 2014
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BAO01-11 会場:502 時間:4 月 28 日 14:15-14:30

火星初期のハビタブル・トリニティ環境と今後の生命探査計画の候補地
Ancient Habitable-Trinity Mars and Future Targeting of potential Signs of Life

Dohm James[1*] ; 丸山 茂徳 [1]
DOHM, James[1*] ; MARUYAMA, Shigenori[1]

[1] 東京工業大学地球生命研究所
[1]Earth-Life Science Institute, Tokyo Institute of Technology

Mars, the most Earth-like planet in our solar system, once had Habitable-Trinity conditions: an interfacing ocean, atmosphere, and nutrient-enriched primordial crustal materials with energy circulation driven by the Sun. Mars is thus considered the best target to search for life beyond Earth, as there are no other planetary bodies in our solar system that record Habitable-Trinity conditions. Following the termination of Habitable Trinity conditions nearly 4.0 Ga, when a strong dynamo shut down prior to the post-heavy-bombardment Hellas and Argyre impact events, the atmosphere was thinning, and plate tectonism was ongoing though waning, life would have found it increasingly difficult to survive at or near the surface, and thus would have migrated to the subterranean to persist. Vent structures, such as those located in the western part of Elysium Planitia where oceans once occupied the Martian surface and long-term magma-water interactions (billions of years) may be still ongoing, as evidenced through pristine lavas, faults that cut youthful surfaces, and geologically-recent flood events, are thus considered to be optimal targets to search for signs of life on Mars. The vent structures were formed by the transferal of subterranean materials to the surface likely due to magma-water interactions. The geologically youthful vent structures could be readily investigated in situ through current mission design.

キーワード: ハビタブル・トリニティ, 生命の存在可能性
Keywords: Habitable Trinity, potential signs of life

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Origin of life component of the Earth
Origin of life component of the Earth

丸山 茂徳 [1*] ; 香内 晃 [2]
MARUYAMA, Shigenori[1*] ; KOUCHI, Akira[2]

[1] 東京工業大学地球生命研究所, [2] 北海道大学
[1]ELSI Tokyo Institute of Technology, [2]Hokkaido University

The Earth is highly depleted in volatile in general. Water is one of them and only 0.023wt% among mass of the solid Earth. If the parental chondrite is carbonaceous with 2.3wt% water, the Earth must have been covered by 380km thick ocean, where too much amount of water was present, hence no life was born because of no supply of nutrients (Maruyama et al., 2013). Origin of water is critical to control the birth of life on rocky planet. Snowline is a concept of the boundary whether solid ice or vapor (gas) is stable at 2.7AU. If the Earth was formed at 1.0AU, the Earth must have been dry, no atmosphere and no ocean.

By this reason, there are several ideas to make the Earth with thinly covering ocean. One of such ideas is that Earth was born as a dry planet with Moon at 4.5-4.6Ga, followed by late bombardments to transport water components to the Earth at 4.4Ga (Maruyama et al., 2013).

Here we propose that late bombardment delivered not only water component but also carbon and nitrogen together at 4.4Ga. The organic lines are present within a narrow region around 2.1AU which is much closer to the Earth than the snowline. Asteroids derived from chondritic materials were transported to the Earth at 4.4Ga, and their organic matters turned to be primordial atmosphere from which primordial ocean was born. C and N with respect to O and H are enriched to make reduced atmospheric composition which could be favorable to synthesize complex organic compounds at the interface between atmosphere and ocean.

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BAO01-P01 会場:3 階ポスター会場 時間:4 月 28 日 18:15-19:30

宇宙ダスト上のアミノ酸生成過程についての理論的研究
Theoretical investigation of amino acid formations on interstellar dusts

木立 佳里[1*] ; 梅村 雅之[1] ; 小松 勇[1] ; 栢沼 愛[1] ; 庄司 光男[1] ; 矢花 一浩[1] ; 白石 賢二[2]
KIDACHI, Kaori[1*] ; UMEMURA, Masayuki[1] ; KOMATSU, Yu[1] ; KYANUMA, Megumi[1] ; SHOJI, Mitsuo[1] ; YABANA, Kazuhiro[1] ; SHIRAISHI, Kenji[2]

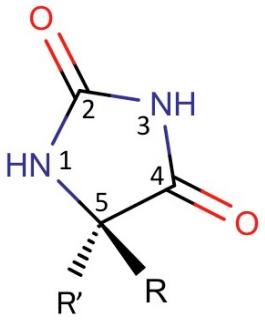
[1] 筑波大学, [2] 名古屋大学
[1]University of Tsukuba, [2]Nagoya University

Molecular evolution in the interstellar space remains unsolved. Formations of molecules in space have been extensively studied by experiments and space observations. Formations of complex organic molecules are expected in the interstellar space. In fact, some amino acids were found in meteorites and amino acids were detected after UV irradiation of interstellar ice analogs.

In the amino acid formation in space, many precursors and molecular evolution pathways are expected. Among these possible pathways, it is very important to know the energy profiles and molecular structures in the major formation pathways. In this study, possible amino acid formation pathways are investigated by using accurate quantum chemistry methods at the density functional theory levels.

Two formation pathways of glycine and alanine were examined: (1) hydrolysis of aminoacetonitrile and (2) hydrolysis of hydantoin derivatives. In the aqueous solution model, Polarizable Continuum Model was used.

Calculated formation energy of glycine is the most stable in the formation pathway in vacuum and no excessively stable intermediates existed. In aqueous solution, hydantoin pathway was slightly unstabilized. In conclusion, glycine production is considered to be occured easily if the components exist. Similar trend is expected for the alanine production.



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BAO01-P02 会場:3 階ポスター会場 時間:4 月 28 日 18:15-19:30

ISS/JEM 曝露部利用実験たんぽぽ：宇宙塵捕集計画と地上実験
Cosmic dusts capture on the International Space Station: Progress of the ground-based experiment

藪田 ひかる [1] ; 緒方 雄一朗 [1*] ; 奥平 恭子 [2] ; 小林 憲正 [7] ; 三田 肇 [6] ; 中嶋 悟 [1] ; 森脇 太郎 [3] ; 池本 夕佳 [3] ; 長谷川 直 [4] ; 田端 誠 [4] ; 横堀 伸一 [5] ; 今井 栄一 [8] ; 河口 優子 [5] ; 杉野 朋弘 [5] ; 浜瀬 健司 [15] ; 福島 和彦 [9] ; 青木 弾 [9] ; 野口 高明 [10] ; 土山 明 [11] ; 中村 智樹 [12] ; 伊藤 元雄 [13] ; 三河内 岳 [14] ; 矢野 創 [4] ; 山岸 明彦 [5] ; たんぽぽ ワーキンググループ [4]
YABUTA, Hikaru[1] ; OGATA, Yuichiro[1*] ; OKUDAIRA, Kyoko[2] ; KOBAYASHI, Kensei[7] ; MITA, Hajime[6] ; NAKASHIMA, Satoru[1] ; MORIWAKI, Taro[3] ; IKEMOTO, Yuka[3] ; HASEGAWA, Sunao[4] ; TABATA, Makoto[4] ; YOKOBORI, Shin-ichi[5] ; IMAI, Eiichi[8] ; KAWAGUCHI, Yuko[5] ; SUGINO, Tomohiro[5] ; HAMASE, Kenji[15] ; FUKUSHIMA, Kazuhiko[9] ; AOKI, Dan[9] ; NOGUCHI, Takaaki[10] ; TSUCHIYAMA, Akira[11] ; NAKAMURA, Tomoki[12] ; ITO, Motoo[13] ; MIKOUCHI, Takashi[14] ; YANO, Hajime[4] ; YAMAGISHI, Akihiko[5] ; TANPOPO, Wg[4]

[1] 大阪大学理学研究科, [2] 会津大学, [3] 高輝度光科学研究センター, [4] 宇宙科学研究所, [5] 東京薬科大学, [6] 福岡工業大学, [7] 横浜国立大学, [8] 長岡技術科学大学, [9] 名古屋大学, [10] 茨城大学, [11] 京都大学, [12] 東北大学, [13] 海洋研究開発機構, [14] 東京大学, [15] 九州大学
[1]Osaka University, Department of Earth and Space Science, [2]University of Aizu, [3]SPring-8, [4]JAXA, [5]Tokyo University of Pharmacy and Life Science, [6]Fukuoka Institute of Technology, [7]Yokohama National University, [8]Nagaoka University of Technology, [9]Nagoya University, [10]Ibaraki University, [11]Kyoto University, [12]Tohoku University, [13]JAMSTEC, [14]Tokyo University, [15]Kyusyu University

Introduction: Organic matter in interplanetary dust particles (IDPs) records the primitive chemical history in the early Solar System as well as it is thought to have delivered the building blocks of life to the early Earth (Chyba and Sagan, 1992). The Japanese Astrobiology working group, Tanpopo, is planning to collect the IDPs using a low-density silica aerogel (0.01 g/cm^3) (Tabata et al. 2011) on the International Space Station (Yamagishi et al. 2009). The mission has a great advantage that collection of the pristine IDPs without atmospheric entry heating and terrestrial contamination will be expected. One thing that has to be considered is a possible modification of the chemical composition of organic matter in IDPs upon their high velocity impact to the aerogel. This issue has been also concerned in the Stardust cometary dust sample return mission. Although the laboratory simulations have been conducted to study the alteration of minerals (Okudaira et al. 2004; Noguchi et al. 2007), the alteration of organics under a realistic condition has not been well understood. As a ground-based experiment, we have conducted a laboratory experiment of aerogel capture of Murchison meteorite powder at 4 km/s using a two-stage light gas gun, in order to evaluate the extent of modification of organic matter in the meteorite.

Experimental: The Murchison meteorite powder (˜500 ug) of a particle diameter of 30-100 um in a polycarbonate sabot was shot at ˜4 km/s using a two-stage light gas gun at JAXA/ISAS. The penetrations of the meteorite powder formed ˜70 tracks of ˜10 mm length in aerogel. Six terminal particles were extracted from the aerogel tracks using a tungsten needle and were pressed between two Al foils. The particles on the Al foils were analyzed by micro-Fourier transmission infrared (FTIR) spectroscopy at the beamline 43IR, Spring-8 and Osaka Univ., and micro-Raman spectroscopy at Osaka Univ. For a comparison, pre-shot Murchison meteorite powder was analyzed by these micro-spectrometers.

Results and discussion: The IR imaging detected the regions of absorptions of aliphatic carbons, CH3 at 2960cm^{-1} and CH2 at 2920cm^{-1} within the two Murchison terminal particles captured by aerogel. Thus, organic matter is survived through the high velocity impact at 4 km/s. The spectral intensities of aliphatic carbons in the terminal particles are slightly lower than those in the pre-shot Murchison meteorite. CH2/CH3 ratios obtained from the IR spectra of the terminal particles were 0.3 ? 3, while those of the pre-shot sample were 1.3 ? 2. The difference in the ratios may be reflected by modification of aliphatic chains of organic macromolecules in the meteorite, e.g., demethylation, methylation, or cracking, due to the high velocity impact heating. From the two terminal particles, D- and G- bands, which are derived from carbonaceous matter, were detected by micro-Raman analyses. Peak widths and positions of the two bands showed similar values to those for pre-shot Murchison meteorite. Thus, modification of aromatic structures after the aerogel capture is unlikely. Although relative amounts of organics were low in the four other terminal particles, this may be reflected by original heterogeneity of the meteorite.

キーワード: ISS/JEM 曝露部, 宇宙塵, 有機物, アストロバイオロジー, 生命の起源, エアロゲル
Keywords: International Space Station, Cosmic dusts, Organic matter, Astrobiology, Origin of life, Aerogel

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軽ガス銃を用いた小惑星衝突模擬実験によるアミノ酸合成の可能性
Possibility of production of amino acids by impact reaction using a light-gas gun as a simulation of asteroid impacts

大河内 一輝 [1*] ; 三重野 哲 [2] ; 近藤 和彦 [1] ; 長谷川 直 [3] ; 黒澤 耕介 [4]
OKOCHI, Kazuki[1*] ; MIENO, Tetsu[2] ; KONDO, Kazuhiko[1] ; HASEGAWA, Sunao[3] ; KUROSAWA, Kosuke[4]

[1] 静岡大学大学院　理学研究科, [2] 静岡大学創造科学技術大学院, [3] 宇宙科学研究所/宇宙航空研究開発機構, [4] 千葉工業大学　惑星探査研究センター
[1]Dept.Physics, Shizuoka Univ., [2]Grad.School of Sci. and Technol, Shizuoka Univ., [3]ISAS/JAXA, [4]Planetary Exploration Research Center, Chiba Institute of Technology

We are interested in the production process of amino acids in space. Especially, asteroids coming to Titan satellite have made impact reaction on the surface including nitrogen gas, water ice and methane. On the Titan surface, various material, produced by the impact reactions, have been stored under low temperature and dark condition. To do the simulation experiment, a JAXA 2-stage light-gas gun has been used. A projectile with 6.5km/s of speed hits a water + iron target in 1 atm of nitrogen gas, causing an impact reaction. Figure 1 shows a crater on the target. Figure 2 shows produced black soot which deposited onto the aluminum sheet. The samples produced are carefully collected and analyzed by HPLC, FTIR, TOF-MS. As a result of HPLC, peaks suggesting the existence of glycine and alanine in the samples produced were confirmed.
Keywords: impact reaction, gas gun, Titan, asteroid, amino acid, HPLC

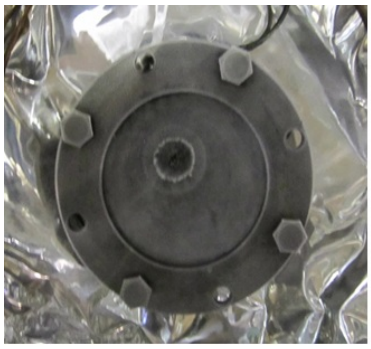

Fig.1 A crater on the target.

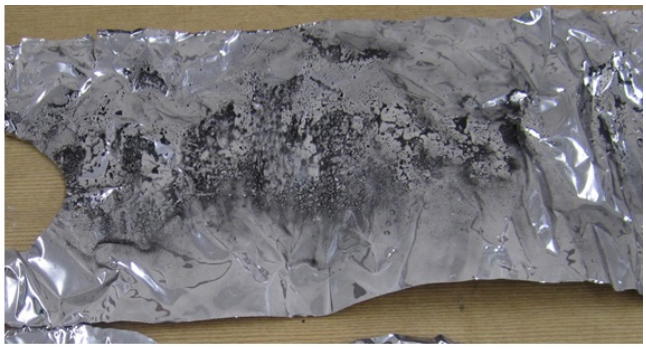

Fig.2 Produced black soot deposited onto the aluminum sheet.

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火花放電および陽子線照射による弱還元型模擬原始大気からのアミノ酸生成
Amino acid formation from simulaed mildly-reducing primitive atmospheres by spark discharges and proton irradiation

伊勢 絢一 [1*] ; 金子 竹男 [2] ; 大林 由美子 [2] ; 福田 一志 [3] ; 小栗 慶之 [3] ; 小林 憲正 [4]
ISE, Jun-ichi[1*] ; KANEKO, Takeo[2] ; OBAYASHI, Yumiko[2] ; FUKUDA, Hitoshi[3] ; OGURI, Yoshiyuki[3] ; KOBAYASHI, Kensei[4]

[1] 横浜国立大学大学院工学府, [2] 横浜国立大学大学院工学研究院, [3] 東京工業大学大学院理工学研究科, [4] 横浜国立大学，自然科学研究機構
[1]Grad. School of Eng., Yokohama Natl. Univ., [2]Faculty of Eng., Yokohama Natl. Univ., [3]Grad. School of Sci. & Eng., Tokyo Inst. Tech., [4]Yokohama National University, NINS

原始地球上での有機物の生成を考える上で，原始大気の組成，特にその酸化還元状態が重要である。Miller は，メタン，アンモニアを多く含む模擬原始大気中で火花放電を行い，アミノ酸の生成を確認した。しかし，今日では原始地球大気は，中性ないし弱還元型と考えられている。どの程度まで還元的であったならば，原始地球大気中でのアミノ酸生成が可能かを調べるため，種々の混合比の二酸化炭素，メタン，窒素，水蒸気の混合気体に火花放電，もしくは陽子線照射を行い，生成物中のアミノ酸の定量を行った。

火花放電の場合は，弱還元型（二酸化炭素：メタン=7:3) の場合でもアミノ酸生成が困難となったが，陽子線照射の場合はさらに還元性の弱い二酸化炭素：メタン=9.5:0.5 の場合でもアミノ酸が生成した。このことは，原始大気組成により，アミノ酸生成に必要なエネルギー源が異なることを示す。

キーワード: 弱還元型原始大気, 火花放電, 陽子線照射, 生命の起源, アミノ酸
Keywords: mildly-reducing primitive atmospheres, spark discharge, proton irradiation, origins of life, amino acids

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模擬海底熱水系におけるアミノ酸の安定性と反応
Stability and reactions of amino acids in simulated submarine hydrothermal systems

赤松 亮太[1*] ; バラサンティラン クーハン[1] ; 大林 由美子[2] ; 金子 竹男[2] ; 小林 憲正[2]
AKAMATSU, Ryota[1*] ; BALASANTHIRAN, Kuhan C.[1] ; OBAYASHI, Yumiko[2] ; KANEKO, Takeo[2] ; KOBAYASHI, Kensei[2]

[1] 横浜国立大学大学院工学府, [2] 横浜国立大学大学院工学研究院, [3] 自然科学研究機構
[1]Grad. School or Eng., Yokohama Natl. Univ., [2]Faculty of Eng., Yokohama Natl. Univ., [3]National Institutes of Natural Sciences

1970 年代末の海底熱水噴出孔の発見は，生命起源研究に大きなインパクトを与えた。それまで，ミラーの実験などにより原始大気中での有機物生成の重要性が考えられていたが，惑星科学の進歩とともに，原始大気が強還元型でないと考えられるようになり，そのような環境下でのアミノ酸などの有機物の生成が限定的とみなされるようになったためである。海底熱水噴出孔では非還元的な地球を考えた場合でも局所的な強還元的な場を保持していると考えられ，有機物の生成・進化に有利と考えられた。さらに，マグマの熱による海水の加熱とそれが冷海水中に噴出することによる急冷，熱水中に溶け出した高濃度の金属イオンやシリカの触媒作用なども化学進化に有利に働くことが期待できる。

海底熱水噴出孔での有機物進化の研究のため，室内模擬実験が多数行われてきた。初期の実験では，閉鎖系のオートクレーブが用い，種々の試料をガスで加圧後に加熱し，その生成物を調べることが多かった。しかし，オートクレーブでは，海底熱水噴出孔の大きな特色である，加熱された海水の急冷（quenching）の効果を検証することができない。そこで，海底熱水系のよりよい模擬のため，種々のフローリアクターが考案された。

本研究では，海底熱水噴出孔での化学進化，特にアミノ酸の重合に関して，オートクレーブおよびフローリアクターを用い，それらの特性の比較とそれらの中でのアミノ酸重合物の生成の可能性の検証を行った。

キーワード: 海底熱水系, アミノ酸, 生命の起源, フローリアクター
Keywords: submarine hydrothermal systems, amino acids, origins of life, flow reactor

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メイラード・タイプ反応で生じる微小球状有機物の形態観察
Scanning electron microscopic observation of organic microspherules formed by Maillard-type reaction

高橋 絢子 [1*] ; 薮田 ひかる [1]
TAKAHASHI, Ayako[1*] ; YABUTA, Hikaru[1]

[1] 大阪大学大学院理学研究科宇宙地球科学専攻
[1]Osaka University, Department of Earth and Space Science

It has been suggested that organic microspherules played a role as a physical container to maintain catalytic molecules and their reaction intermediates at concentrations high enough to sustain catalysis in prebiotic chemistry on the early Earth (Weber, 2005). Experimental studies on the formation of organic microspherules from a variety of organic compounds, such as amino acids (Fox and Harada, 1958), gelatin and gum arabic (Oparin, 1976), organic extracts from meteorite (Deamer, 1985; Deamer and Pashley, 1989), interstellar organic analogue (Dworkin et al. 2001), fatty acids and polycyclic aromatic hydrocarbons (Groen et al. 2012), formaldehyde and ammonia (Cody et al. 2009; Kebukawa et al. 2013) have been reported. However, the formation process and stability of these organic microspherules have been unexplored. In this study, sizes, shapes, and distributions of organic microspherules formed during the progress of Maillard-type reaction of formaldehyde and ammonia were investigated.

Experimental:
Paraformaldehyde (120mg), glycolaldehyde (120mg), ammonium hydroxide (54ul), calcium hydroxide (30mg) in 2ml of water in a glass tube was heated at 50-90 degrees C for 71-720 hours. For comparison, the samples without ammonium hydroxide were heated under the same conditions. After heating, the sample solutions were centrifuged. The precipitated material were rinsed with 2N HCl to dissolve calcium, and dried at 50 degrees C to obtain organic solids. The organic solid samples were pressed on a indium plate, gold-coated, and observed by a scanning electron microscopy (SEM).

Results and discussion:
After several minutes in heating, all the sample solutions turned yellow and eventually turned brown to black. Organic solids were produced at 90 degrees C but 50 degrees C. The yields of organic solids from sample solutions with ammonia were 10 times higher than those without ammonia. The yields gradually increased during heating. While distorted-shaped aggregates are produced from the samples heated for 71-120 hours, micron-sized organic microspherules (0.4-4.0 um) were observed from those heated for 240-720 hours. The samples with ammonia show perfectly round shapes of microspherules. Some microspherules are large and oval in the sample heated for 480 hours. The sizes of the microspherules increased with heating time. Organic solids produced by the same reaction as this study's at 90 degrees C for 72 hours consist of approximately equal abundances of aromatic and aliphatic carbons (Kebukawa et al. 2013). This molecular composition could result in amphiphilicity that is related to formation of the stable microspherules observed in this study. Formaldehyde and ammonia are thought to have been commonly present on the early Earth, and thus the organic microspherules formed by these molecules which proceed polymerization efficiently under mild conditions, could have played a role as a precursor of prebiotic cell membrane.

Keywords: organic microspherules, Maillard reaction, prebiotic cell membrane

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DNA 蛍光色素を用いたエアロゲルに衝突した微生物の検出
Fluorescence imaging of microbe-containing micro-particles that had been shot from a two-stage light-gas gun into an ult

河口 優子[1*] ; 杉野 朋弘[2] ; 田端 誠[1] ; 奥平 恭子[3] ; 今井 栄一[4] ; 矢野 創[1] ; 長谷川 直[1] ; 薮田 ひかる[5] ; 小林 憲正[6] ; 河合 秀幸[7] ; 三田 肇[8] ; 橋本 博文[1] ; 横堀 伸一[2] ; 山岸 明彦[2]
KAWAGUCHI, Yuko[1*] ; SUGINO, Tomohiro[2] ; TABATA, Makoto[1] ; OKUDAIRA, Kyoko[3] ; IMAI, Eiichi[4] ; YANO, Hajime[1] ; HASEGAWA, Sunao[1] ; YABUTA, Hikaru[5] ; KOBAYASHI, Kensei[6] ; KAWAI, Hideyuki[7] ; MITA, Hajime[8] ; HASHIMOTO, Hirofumi[1] ; YOKOBORI, Shin-ichi[2] ; YAMAGISHI, Akihiko[2]

[1] 宇宙航空研究開発機構宇宙科学研究所, [2] 東京薬科大学, [3] 会津大学, [4] 長岡技術科学大学, [5] 大阪大学, [6] 横浜国立大学, [7] 千葉大学, [8] 福岡工業大学
[1]ISAS/JAXA, [2]Tokyo University of Pharmacy and Life Sciences, [3]University of Aizu, [4]Nagaoka University of Technology, [5]Osaka University, [6]Yokohama National University, [7]Chiba University, [8]Fukuoka Institute of Technology

We previously proposed an experiment (the Tanpopo mission) to capture microbes and organic compounds on the Japan Experimental Module of the International Space Station. An ultra low-density silica aerogel will be exposed to space for one year. After retrieving the aerogel, particle tracks and particles found in it will be visualized by fluorescence microscopy after staining it with a DNA-specific fluorescence dye. In preparation for this study, we simulated particle trapping in the aerogel so that methods could be developed to visualize the particles and their tracks. During the Tanpopo mission, particles that have an orbital velocity of about 8 km/s are expected to collide with the aerogel. To simulate these collisions, we shot *Deinococcus radiodurans*-containing Lucentite particles into an aerogel from a two-stage light-gas gun (acceleration 4.2 km/s). The shapes of the captured particles and their tracks and entrance holes were recorded with a microscope/camera system for further analysis. The size distribution of the captured particles was smaller than the original distribution, suggesting that the particles had fragmented. We were able to distinguish between microbial DNA and inorganic compounds after staining the aerogel with the DNA-specific fluorescence dye SYBR green I as the fluorescence of the stained DNA and the autofluorescence of the inorganic particles decay at different rates. The developed methods are suitable to determine if microbes exist at the International Space Station altitude.
Keywords: Aerogel, Space experiment, Hypervelocity impact experiment, DNA-specific fluorescence dye.

Keywords: Aerogel, Space experiment, Hypervelocity impact experiment, DNA-specific fluorescence dye

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酵素活性を利用した極限環境生命探査法の検討ーホスファターゼとカタラーゼー
Studies on life detection methods by using enzymatic activities: Phosphatase and Catalase

青木 耕平[1*] ; 栗塚 泰平[1] ; 大林 由美子[1] ; 小川 麻里[2] ; 吉村 義隆[4] ; 三田 肇[3] ; Navarro-Gonzalez Rafael[5] ; 金子 竹男[1] ; 小林 憲正[6]
AOKI, Kohei[1*] ; KURIZUKA, Taihei[1] ; OBAYASHI, Yumiko[1] ; OGAWA, Mari[2] ; YOSHIMURA, Yoshitaka[4] ; MITA, Hajime[3] ; NAVARRO-GONZALEZ, Rafael[5] ; KANEKO, Takeo[1] ; KOBAYASHI, Kensei[6]

[1] 横浜国立大学大学院工学研究院・工学府, [2] 安田女子大学教育学部, [3] 玉川大学農学部, [4] 福岡工業大学工学部, [5] メキシコ国立自治大学, [6] 横浜国立大学・自然科学機構
[1]Graduate School of Engineering, Yokohama National University, [2]Faculty of Education, Yasuda Women's University, [3]College of Agriculture, Tamagawa University, [4]Faculty of Engineering, Fukuoka Institute of Technology, [5]National Autonomous University of Mexico, [6]Yokohama National University and Natural Institutes of Natural Sciences

南極，砂漠，火星などの極限環境における生命探査法として，ホスファターゼ活性やカタラーゼ活性を用いた酵素活性測定法を検討した。

キーワード: 極限環境, 火星, 生命探査, 酵素活性, ホスファターゼ, カタラーゼ
Keywords: extreme environments, Mars, life detection, enzymatic activities, phosphatase, catalase

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Molecular approach to the characterisation of Sri Lanka red rain cells
Molecular approach to the characterisation of Sri Lanka red rain cells

三宅 範宗[1*] ; 松井 孝典[1] ; Wickramasinghe Chandra[2] ; Wallis Jamie[3] ; Wallis Daryl[2] ; Wickramarathne Keerthi[4] ; Samaranayake Anil[4]
MIYAKE, Norimune[1*] ; MATSUI, Takafumi[1] ; WICKRAMASINGHE, Chandra[2] ; WALLIS, Jamie[3] ; WALLIS, Daryl[2] ; WICKRAMARATHNE, Keerthi[4] ; SAMARANAYAKE, Anil[4]

[1] 千葉工業大学惑星探査研究センター, [2]Buckingham Centre for Astrobiology, University of Buckingham, Buckingham, UK, [3]School of Mathematics, Cardiff University, Cardiff, UK, [4]Medical Research Institute, Colombo, Sri Lanka
[1]Planetary Exploration Research Center, Chiba Institute of Technology, Chiba, Japan, [2]Buckingham Centre for Astrobiology, University of Buckingham, Buckingham, UK, [3]School of Mathematics, Cardiff University, Cardiff, UK, [4]Medical Research Institute, Colombo, Sri Lanka

The recent mysterious phenomenon that has attracted much attention is that of the red rain which fell in Polonnaruwa, Sri Lanka, on 13 November 2012. The microbial content in red rain shows generic similarities to that of the Indian red rain which fell in 2001. The morphological property of those microbes has been well documented [1,2]. Various microscopic analyses of our Sri Lankan red rain sample indicate that the defining red rain cells (RRC) exist in the presence of other microorganisms including diatoms. In our past paper, the ultrastructure of RRC shows that it is possibly a spore-form and so allowing them to thrive in the extreme upper biosphere conditions [3]. We also show the presence of uranium in the abnormally thick cell wall of RRCs.

In this report, we present the molecular approach to the characterisation of microbial communities in red rain and reveal the genus of RRCs. A beads-beating protocol is carried out for the efficient extraction of DNA and denaturing gradient gel electrophoresis (DGGE) for the analysis of microbial communities.

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キーワード: 赤い雨, 極限環境微生物, ポロンナルワ
Keywords: Red rain, Extremophile, Polonnaruwa

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縞状鉄鉱床の形成で最古の有機炭素を生成した機構
The mechanism that had formed the oldest organic carbon with the banded ironstone formations

唐澤 信司 [1*]
KARASAWA, Shinji[1*]

[1] 宮城工業高等専門学校 (名誉教授)
[1]Miyagi National College of Technology (Professor emeritus)

M. T. Rosing は約 38 億年前の縞状鉄鉱床が形成された時期に生成された西グリーンランドの堆積岩の中に最古の有機炭素を検出したと報告した [1]。その報告によれば、その堆積岩に含まれた 2~5 μ のグラファイトの微粒子の炭素同位体比 ($^{12}C/^{13}C$) の値が無機炭素のそれより大きい。ところが、連鎖反応を行う分子のシステムにより実現している光合成によって最古の有機炭素が生成されたとすることはできない。本報告において、著者は縞状鉄鉱床の形成によって生成された浮遊物に ^{12}C が少し多く取り込まれた仕組みを提案する。

炭酸水に鉄の微粉末を加えると、写真 1 に示すような現象が観察できる。水底の鉄の微粒子の表面に気泡ができて、その気泡が鉄の微粒子を水底から水面に浮上させる。炭素の電気陰性度は水素より大きいので、鉄の酸化によって、炭酸水の CO_2 から酸素が取り除かれる。自由になった炭素原子は電気陰性度のために鉄と分子間力で結びつき、浮遊物ができる [2]。浮遊物の鉄の原子は酸素と結合して酸化鉄となり、自由になった炭素原子が浮遊物の分子間結合を増強し、外界のエネルギーを得て有機物質が生成される。

約 38 億年前の地球の表面は酸化物や硫化物や炭酸塩などで覆われており、大気には多くの二酸化炭素ガスがあったが、海ができ、その海水温度もある程度の温度以下になり、大気中の二酸化炭素が海水に溶けるようになっていた。そのような状況において火山の噴火が頻繁に発生して多量の鉄の微粒子が放出されて、縞状鉄鉱床が形成された。他方、大気中の二酸化炭素の分子が頻繁に水面に衝突した。それが、分子間結合で構成された浮遊物に含まれた。浮遊物は水面で累積される。そこに、紫外線等によるエネルギーが外部から供給されて、浮遊物の中で有機分子の組織も形成された。やがて、それらが海底に沈殿して堆積した。こうして、大気の二酸化炭素に由来す ^{12}C 炭素同位体が西グリーンランドの堆積岩に取り込まれた。

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[**写真 1**] 炭酸水に鉄の微粉末を加えると気泡が発生し浮遊物ができて集積される様子 (左:作りおいた古いメッシュ#300 の鉄の微粉末、中央:作って新しいメッシュ#300 の鉄の微粉末、右:やや粒が大きいメシュ#200 の鉄の粉末)

キーワード: 38 億年前, 縞状鉄鉱床, 有機炭素, 二酸化炭素, 炭素同位体比
Keywords: 3.8 billion years ago, Banded iron formation, Organic carbon, Carbon dioxide, Carbon isotope ratio