Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

BAO01-01 Room:301A Time:May 21 09:00-09:30

Estimated Abundances of a Precursor of Glycine, CH_3NH_2

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In is widely accepted that prebiotic chemical evolution from small to large and complex molecules would have resulted in the Origin of Life. On the other hands there have been conflicting two views regarding where inorganic formation of organic molecules (hereafter OMs) occurred in the early Earth, in the Earth or out of the Earth. Ehrenfreund et al. (2002) indicated that exogenous delivery of OMs to the early Earth could be larger than their terrestrial formation by three orders of magnitude. If amino acids are formed in interstellar clouds, significant amount of them may be delivered by comets and/or asteroids to (extra-solar) planets. Detection of amino acids would accelerate the discussion concerning the universality of "life".

So far, many trials to detect simplest amino acid, glycine (CH_2NH_2COOH), were made towards Sgr B2 and other high-mass forming regions, but none of them were successful due to insufficient sensitivities and spatial resolution of telescopes. This is the background that detection of amino acids and other prebiotic in the Universe is one of the key science targets for ALMA. However we need to have carefully selected good candidate sources for amino acids before conducting searches for amino acids by ALMA since lines could be contaminated by other molecular lines. One idea would be to survey precursors of amino acids; higher abundances sources of precursors would be amino acid rich sources.

Although the chemical evolution of interstellar N-bearing OMs is poorly known, methylamine (CH_3NH_2) is proposed as a precursor to glycine; theoretical and laboratory studies have indicated that glycine is formed on icy grain surface from methylamine and CO_2 through UV irradiation (Holtom et al. ApJ, 626, 940 (2005), Kim and Kaiser et al., ApJ, 729:68 (2011)). These studies also suggest that methylamine can be formed from abundant species, CH_4 and NH_3, on icy dust surface. Although CO_2 is widely known in molecular clouds, distribution of methylamine is poorly known. Further methylene imine (CH_2NH) would be related to CH_3NH_2. These species are thought to be formed through hydrogenation (addition of hydrogen) to HCN on dust surface (Dickens et al., 1997, Kim and Kaiser et al. 2011): HCN -> CH_2NH -> CH_3NH_2. This is similar to the hydrogenation of CO to form CH_3OH: CO -> H_2CO -> CH_3OH.

The first detection of methylamine was made by Kaifu et al. (1974). But even now, CH_3NH_2 is known toward two objects (Orion KL and Sgr B2) only. CH_2NH has been reported only in Sgr B2, W51, Orion KL, and G34.3 (Dickens et al.1997).

Therefore it would be crucial to estimate abundances of CH_3NH_2 and CH_2NH by using a chemical reaction network, which may be compared with observations. In this paper we present preliminary results of estimated abundances of these species, which would provide good guidance in finding good glycine sources and in understanding poorly known chemistry of N-bearing organic molecules in the Universe.

Keywords: Organic Molecules in Space, Chemical Evolution, Planetary Formation

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BAO01-02 Room:301A Time:May 21 09:30-09:45

Near-Infrared Circular Polarization Images of NGC 6334-V: Implication for Astrobiology

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We present results from deep imaging linear and circular polarimetry of the massive star-forming region NGC 6334-V. These observations show high degrees of circular polarization (CP), as much as 22% in the Ks band, in the infrared nebula associated with the outflow. The CP has an asymmetric positive/negative pattern and is very extended (~80" or 0.65 pc). Both the high CP and its extended size are larger than those seen in the Orion CP region. Three-dimensional Monte Carlo light-scattering models are used to show that the high CP may be produced by scattering from the infrared nebula followed by dichroic extinction by an optically thick foreground cloud containing aligned dust grains. Our results show not only the magnetic field orientation of around young stellar objects, but also the structure of circumstellar matter such as outflow regions and their parent molecular cloud along the line of sight. This is the second case to support the large CP in scattering protostellar nebulae as a possible explanation for the extraterrestrial origin of homochirality of life on Earth.

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BAO01-03 Room:301A Time:May 21 09:45-10:00

The energy transfer calculation of light harvesting systems for detecting biomarker on extrasolar planets

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A large number of extrasolar planet candidates have been detected by Kepler. Moreover the planets in habitable zone have already been detected, and ELP (Earth-like planet) is expected to be discovered. As detecting signs of life from the spectrum of ELPs in future, several indicators called as biomarkers or biosignatures were proposed [1]: (1) molecule absorption line, such as O_2, CH_4, and (2) red edge, which is a strong contrast in NIR (~700-750 nm) that derives from plant's feature. Red edge comes from absorption in visible by the chlorophyll, which is one of the photosynthetic pigments, and reflectance in NIR due to the structural features such as cell wall, air space of leaf and so on. The spectrum considered as red edge is observed by remote sensing or earthshine [2].

However, it is not guaranteed that red edge on extrasolar planets is detected as same wavelength on Earth. In fact, the photosynthetic organisms on Earth harvest light according to the surrounding environments to efficiently use light having a variety of wavelength that reaches, and of course their spectrum varies. In case of photosynthesis in extrasolar planets, photosynthetic organisms should evolve as optimized to utilize their principal star. We focus on the fundamental light harvesting mechanism and aim to propose how to detect the spectrum of the planet orbiting the different spectrum types of star otherwise Sun. At first, we adopted our models to photosynthetic organisms on Earth and compared with the experimental data. The light harvesting antenna in these organisms differs from kinds of pigments and their conformations.

We investigated the mechanism how the organisms harvest light by quantum mechanical calculation. However, because of the cost difficulty, we introduced an approximation instead of calculating all the electrons in the system. First, we calculated the excitation energies and the transition moments from the ground state to the excited states in the pigments by TDDFT (time-dependent density functional theory) [3]. Then, by introducing the transition moments of each pigment to the antenna, which consists of several kinds of pigments (other environment: proteins, solvent,...), we assume as an approximation that one pigment has the excited energy and interacts with the other pigments by the dipole-dipole interaction. When the light, as it seems to be considered as traveled from a star to a surface of an extrasolar planet, induces the system, we traced the time evolution of the energy transfer by solving Liouvile equation. We dealt the light with an external potential. By this method, we can calculate the spectral intensity and energy efficiency.

In certain types of bacteria, the contrast like red edge can be detected, although the contrast is weaker than that of plants. In purple bacteria, red edge is not detected or emerges in longer wavelength (~1013-1025 nm). In addition, its structure of the antenna is simple so that we adopted easily our model to the bacteria. The calculated spectrum has a good agreement with the experimental result from purple bacteria. We will extend our model to the other species. By comparing the light harvesting mechanisms showing red edge and no red edge, we can examine how red edge emerges in photosynthetic organisms. For the other inducing light condition, we will survey the light harvesting mechanism optimized to extrasolar planets.

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Keywords: extrasolar planet, biomarker, quantum mechanical calculation

Japan Geoscience Union Meeting 2013
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BAO01-04 Room:301A Time:May 21 10:00-10:15

Organic compounds in interplanetary dust particles and their relevance to origins of life

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Organic compounds including amino acid precursors and nucleic acid bases have been detected in carbonaceous chondrites, and glycine was detected from the captured cometary dust. These organics have been discussed in the context of possible organic sources for the first terrestrial life. It was suggested that more organic carbons were delivered to the early Earth by interplanetary dust particles (IDPs) than by meteorites or comets [1]. A demerit of IDPs for the carriers of extraterrestrial organics is that IDPs are so small that they are directly exposed to solar radiation that might decompose organics. Thus the presence of bioorganics in IDPs is expected, but it is difficult to judge it since IDPs (or micrometeorites) are so small and they have been collected in the terrestrial biosphere. Thus it would be of importance to study possible alteration of IDP organics in space environments, and to collect pristine IDPs out of the terrestrial biosphere.

Since carbonaceous chondrites and comets contain such organic compounds as amino acids or their precursors, IDPs that seem to be formed from meteorites and comets can also contain them. In order to study possible alteration of bioorganic compounds in IDPs, amino acids, amino acid precursors and nucleic acid bases were irradiated with high-energy particles and high-energy photons to simulate the actions of cosmic rays and solar radiation, respectively. We used glycine and isovaline as free amino acids since they are found abundant in carbonaceous chondrites. Their possible precursors, hydantoin and 5-ethyl-4-methyl hydantoin, and complex amino acid precursors synthesized from a mixture of CO, NH_3 and H2O (hereafter referred to as CAW) [2] were also used as irradiation targets. These molecules were irradiated with continuous light from soft X-rays to IR (hereafter referred to as soft X-rays) at the beam line 6 of NewSUBARU (the synchrotron facility of University of Hyogo). They were also irradiated with heavy ions from HIMAC (NIRS, Chiba). Irradiated samples were evaluated by amino acid analysis after acid-hydrolysis and/or by C-XANES by using the beam line 5 of NewSUBARU. Nucleic acid bases (adenine etc.) were also irradiated with soft X-rays and with heavy ions, and recovery was also determined by HPLC.

Amino acid precursors were more stable against soft X-rays than free amino acids. Water-insoluble products were formed after soft X-rays irradiation. Nucleic acid bases were more stable than amino acids and their precursors against the irradiation. Heavy ions were generally less effective than soft X-rays for decomposition or alteration of the molecules examined.

We are planning a novel astrobiology mission named Tanpopo by utilizing the Exposed Facility of Japan Experimental Module (JEM/EF) of the International Space Station (ISS). Two types of experiments will be done in the Tanpopo Mission: Capture experiments and exposure experiments.

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Keywords: interplanetary dust particles, amino acids, origins of life, complex organic compounds, soft X-rays, the Tanpopo Mission

BAO01-05 Room:301A Time:May 21 11:00-11:30

Interdisciplinary Perspectives on Abiogenesis

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I will report on new interdisciplinary activities at the Institute for Advanced Study, in Princeton, NJ, USA, focused on the origins of life. We have recently started a series of weekly meetings, involving mathematicians, physicists, chemists, biologists, astrophysicists and others. Our discussions range from important technical details to more general meta-level discussions concerning the flow of information through biological networks and the characteristics of life in general, on Earth and possibly elsewhere in the Universe. We include scholars in humanities and linguistics, since there are interesting parallels between the origins of culture and the origins of life, and in general with the origins of "systems", where unreliable parts are used to create reliable systems. My work is inspired by my affiliation with ELSI, the new Earth-Life Science Institute at Tokyo Tech, under the WPI program of MEXT.

Keywords: origins of life, flow of information, biological networks, characteristics of life, systems

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BAO01-06 Room:301A Time:May 21 11:30-11:45

Exposure experiments of organic compounds in space environments in the TANPOPO mission

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The Tanpopo mission is a Japanese astrobiological experiment which will be conducted on the Japanese Experiment Module (JEM) of the International Space Station (ISS). The Tanpopo mission consists of six subthemes: 1) capture of microbes in space, 2) exposure of microbes in space, 3) exposure of organic compounds in space, 4) capture of organic compounds (in micrometeoroids) in space, 5) evaluation of ultra low-density aerogel developed for the Tanpopo mission, and 6) capture of space debris at the ISS orbit (approximately 400 km altitude).

Here, we overview the exposure experiment of organic compound in space environment. Since many kinds of organic compounds, especially, amino acids which are ones of most important organic compounds in living organisms, are found from extraterrestrial materials, extraterrestrial and outer-solar environments are thought as the place for the prebiotic organic compound synthesis. Then, it is proposed that the first organisms on the earth was born from the prebiotic organic compounds delivered into the early earth on meteorites, micrometeorites and/or comets. In order to discuss the possibility of the hypothesis, alteration of prebiotic compounds in space environments should be clear. Therefore, we will expose some prebiotic organic compounds on the exposure facility at ISS-JEM.

Glycine, isovaline, hydantoin, ethylmethylhydantoin and complex organics (CAW) are chosen for the exposure. Hydantoin and ethylmethylhydantoin are plausible low molecular weight precursors for glycine and isovaline, respectively. CAW which is a simulated material of interstellar medium prepared by proton radiation into mixture of CO, NH_3 and H_2O is a different type of plausible precursors for amino acids. In the space environments, uv-light and cosmic rays (heavy ions and gamma-rays) will cause the alteration of organic compounds. Therefore, simulation experiments were studied using Xe-excimer lamp (uv 172 nm), synchrotron radiation at NewSUBARU BL06 (uv $>$ 130 nm), 60Co gamma-ray radiation (JAEA Takasaki) and carbon ion beams (290MeV, NIRS). gamma-Ray and heavy ion beam irradiation with dose of ISS environment for one year induced little decomposition of organic compounds. However, uv irradiation was critical for organic compounds. Although almost all glycine and isovaline were decomposed, remains of hydantoin and ehtylmethyl hydantoin were approximately 29% and 72%, respectively, with uv dose of ISS environment for one year. Furthermore, CAW was more stable than hydantoins. Amino acids precursors, especially, complex organics were more stable than free amino acids. Therefore, extraterrestrial amino acids precursors would be effective source for origins of life on the earth. We will demonstrate this conclusion on the ISS-JEM.

In addition, Nakagawa and his colleagues were found that dialanine was formed from alanine films by uv-irradiation. We will demonstrate a peptide synthesis with uv-irradiation in the space environment. Furthermore, piece of meteorite will be also exposed in order to examine the weathering effect in the ISS environment.

Keywords: Tanpopo, exposure of organics, ISS, amino acids

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BAO01-07 Room:301A Time:May 21 11:45-12:00

Effects of borate on the stability of ribose

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RNA is considered an important biomolecule for the origin of life, with its abilities as the carrier of genetic information and catalysts for biological reactions. RNA is composed of phosphoric acid, nucleic acid bases, and ribose. Among them, ribose is the most unstable component. Therefore, accumulation of ribose on the early Earth is an important step for the origin of RNA. Ribose as well as other aldopentoses can be abiotically synthesized by formose reaction in which formaldehyde oligomerize under alkaline conditions. Previous studies showed a stabilization of pentoses in the formose reaction by borate. In this study, we have investigated the effects of borate on the stability of aldopentoses.

Incubation experiments of each four aldopentoses were conducted at approximately 45 degree C with sodium tetraborate decahydrate of three concentrations. The pH of the experimental solution was buffered with calcium hydroxide. The experimental solution was collected at a fixed interval and analyzed with liquid chromatography-mass spectrometry.

In the borate-free experiments, all aldopentoses showed high decrease rates. In borate-containing experiments, formations of pentose-borate complexes were observed. The decrease rates for all aldopentoses were reduced with the concentration of borate. These results indicate that borate can stabilize all aldopentoses. Therefore, borate might have stabilized aldopentoses including ribose and contributed to the formation of primordial RNA on the early Earth.

Keywords: ribose, RNA, borate, origin of life

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BAO01-08 Room:301A Time:May 21 12:00-12:15

A Possible Pathway of Homochirality Accumulation by Oligopeptides

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Although numerous hypotheses have been proposed for chemical-evolutionary explaining the homochirality of biomolecules, most of them have discussed the homochirality of only monomeric compounds like amino acids or monosaccharides. However, the homochirality of monomeric compounds do not always guarantee the homochirality of polymers, because there had been many energy sources which made the chiral compounds decompose in the primitive earth or extraterrestrial environments. The processes or environments to conserve the homochirality must have existed.

This research focuses the homochirality accumulation in polypeptides by oligopeptides. Dimerization of racemic amino acids usually produces diastereomeric dipeptides. If the amino acid is DL-alanine, the condensation reaction gives cyclic and acyclic LL-, LD-, DL-, and DD-diastereomers of Ala-Ala. The total seven diastereomers can be yielded, because cyclic D-Ala-L-Ala and cyclic L-Ala-D-Ala are same compounds (meso-type isomers). The diastereomers are different in the hydrophobicity, decomposition rate, epimerization rate, as well as stereochemistry. Hydrophobicity difference reflects a difference in water solubility to lead the segmentation of the diastereomers in aqueous media. Acylclic heterochiral (LD- and DL-) oligopeptides are usually more hydrophobic than acyclic homochiral (LL- and DD-) oligopeptides.

In the presentation, a scheme of the homochirality accumulation in polypeptides by oligopeptides will be shown with the processes of the segmentation, epimerization, decomposition, and stereospecific condensation of oligopeptides.

Keywords: homochirality, condensation, oligopeptides

BAO01-09 Room:301A Time:May 21 12:15-12:30

GADV peptide/aggregate synthesis using a hydrothermal simulator at elevated temperature

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GADV peptide/aggregate synthesis using a hydrothermal simulator at elevated temperature

Kuhan Chandru, Eiichi Imai, Yumiko Obayashi, Takeo Kaneko and Kensei Kobayashi

GAVD peptide hypothesis was proposed by Ikehara (2009) as a possible alternative that precedes the RNA world hypothesis (Gilbert, 1986) due to many limitations. The hypothesis suggest a very plausible explanation, but has only been experimentally tested by Oba and co workers (2012), in terms of possible peptide formation using heat-drying cycles and their catalytic activities. We would want to examine the formation of GADV aggregates (or peptides) in an simulated hydrothermal system to represent a more realistic prebiotic environment. We have used Gly, L-Asp, L-Asp and L-Val into our Supercritical Water Flow Reactor (SCWFR) at a temperature range of 100-300 Celsius . Our initial results suggest that no visible aggregates (bigger than 0.2micrometer) were seen after the heating of 2 min in the mentioned temperature range. Initial MALDI-TOF-MS are also suggesting that we only obtained a small peaks about m/z 410 within the spectrum lesser what Oba et al (2012) which was 525, 539, 657. Although many hydrothermal simulation experiments has shown the recovery of amino acids (Islam et al 2002; Kohara et al; Kobayashi et al, 1997) and the formation of oligomers (Imai, 1999; Goto et al , 2005) we only believe, that only small aggregation occur and cannot promote bigger oligomers or polymers due to heat and pressure stress. Hence, based on our initial findings, we are very uncertain about the formation of GADV aggregates or peptides in a hydrothermal system if we use free-form amino acids. It would be of interest to investigate the hypothesis by using bound amino acids or amino acid precursors.

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Keywords: GADV, Hydrothermal, prebiotic

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BAO01-10 Room:301A Time:May 21 14:15-14:30

Modeling the rise of oxygen after the Snowball earth: implications for the Paleoproterozoic manganese and iron formation

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Earth's atmosphere and oceans are considered to have experienced stepwise and irreversible oxidation through its history (e.g. [1]), which may have paved the way to the complicated life such as eukaryotes and metazoans [2]. It is interesting to note that geological evidence suggests that a remarkable increase of oxygen concentration has occurred shortly after the Paleoproterozoic Snowball Earth event, based on widespread depositions of manganese and iron oxides immediately above the glacial diamictites found in the Paleoproterozoic sedimentary sequences from the Transvaal Supergroup, South Africa, and the Huronian Supergroup, Canada [3,4]. Carbonate precipitation occurs above the deposition of manganese and iron in both the Transvaal and Huronian Supregroups [3,5], which may represents a climate recovery from the greenhouse condition in the Snowball earth aftermath [3]. In this study we numerically investigated the linkage between a global-scale glaciation and an oxygenation of the atmosphere-ocean system, in the aim of comparing our results to the geological records.

The results of our numerical experiments with a biogeochemical cycle model indicate that the super greenhouse conditions (pCO_2˜0.7 atm and T˜320 K) in the aftermath of the Paleoproterozoic Snowball Earth event significantly enhance the chemical weathering of continents, causing ˜10 times as high as the present levels of nutrient input and the biological productivity. In the consequence of high levels of biological productivity together with a positive feedback in the atmosphere among a rise in oxygen, ozone formation, and UV shielding of methane, the atmospheric oxygen levels rapidly rise from $< 10^{-5}$ PAL to 0.01 PAL (PAL: the present atmospheric level) after the glaciation. The oxygen levels then overshoot to ˜1 PAL in ˜10^6 years after the glaciation due to the high levels of biological productivity sustained by a long-term global warming. Atmospheric oxygen then gradually decreases by oxidizing reducing materials from Earth's interior. Eventually, a steady state of atmospheric oxygen of ˜0.01 PAL is achieved in 10^8 years. Such an irreversible rise in atmospheric oxygen (i.e., from $< 10^{-5}$ PAL to ˜0.01 PAL) is explained by a transition between different steady state of atmospheric oxygen levels [6] caused by a Snowball Earth glaciation and the subsequent perturbations of biogeochemical cycles.

We found that the rapid oxygenation causes the deposition of manganese and iron in the shallow marine environments. Manganese and ferrous iron in the anoxic deep water are driven by thermohaline circulation, immediately oxidized in the shallow marine water within 10^4 years after the glaciation. Assuming deep water is initially saturated with respect to Mn-carbonates, we derive 10^{15} mol of manganese deposition, which would be sufficient to form manganese ore in the Hotazel formation, Transvaal Supergroup (˜8Gt, ˜10^{14} mol of manganese [7]). We also found that calcite precipitation is prevented in the ocean during 10^5 years after the glaciation owing to high atmospheric pCO_2. Our results imply that manganese and iron oxides deposition might precede the carbonate deposition, which is consistent with the geological records found both in the Transvaal and Huronian supergroups [3,4].

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BAO01-11 Room:301A Time:May 21 14:30-15:00

A Simple Astrobiological Scenario to go from the Great Oxygenation Event to the Origination of Eukaryotes

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Taken in the context of Earth History, it is now clear that all previously reported Archean biomarkers indicative of oxygenic photosynthesis are most likely in error, a result of contamination during sampling. Reported geochemical whiffs of oxygen from ABDP-9 are also tightly associated with hydrothermal veins of highly crystalline clinochlore, and are thus metasomatic artifacts from hydrothermal vein deposits. Firm evidence for Archean oxygen simply does not exist.

A much simpler scenario will be presented here in which photosystem-II evolves at ˜ 3.35 Ga, causing the radiation of the Cyanobacterial clade during the Gowganda glaciation. The resulting drawdown of CO2, and destruction of CH4, triggered the Makganyene global (snowball) glaciation, freezing the ocean surfaces for ˜ 50 to 100 Myr, ending at 2.22 Ga. This is immediately followed by the deposition of the Kalahari Manganese Field, which is the oldest firm geological constraint on copious quantities of free O2 in Earth's environment. As there must be a time gap between the evolution of Photosystem-II and the origin of oxidative phosphoralization (aerobic respiration), Earth's carbon cycle must have been extremely out of balance. We interpret the Lomagundi/Jatuli Carbon Isotope excursion (about 2.2 to 2.06 Ga) as precisely this imbalance, where the oxygen produced by photosynthesis, and organic matter produced, could not be easily recycled. The fraction of organic carbon buried increased from the long-term average of about 20% up to about ˜ 75%, yielding isotopic compositions of carbonate as heavy as +15 per mil. Oxygen in the atmosphere is known to have increased to high levels ? perhaps several bars - resulting in the supergene alteration of the ˜ 2.1 Ga iron ores in the Sishen deposit of South Africa during formation of the Hekpoort Paleosol. During this Lomagundi event, the high oxygen levels would be limited by the inability of cyanobacteria to release oxygen against high back pressures, and the remineralization of organic carbon would be accomplished by oxidative weathering of sulfide minerals releasing sulfate, and by the subsequent action of sulfate reducing bacteria to break down the organic carbon.

As the radiation of the Proteobacteria post-dates the radiation of the Cyanobacteria, and the ancestor of the Eukaryotic mitochondria was once a free-living alpha-Proteobacterium, it also follows that the first organelle-bearing eukaryotes must post-date the Makganyene Snowball Earth event. Numerous eukaryotic organelles have ancestry in this bacterial endosymbiont, as do cellular components such as the hydrogenosome in basal Protists.

A puzzling organelle present in both Bacteria and Eukaryotes (including many Protists) is the magnetosome, a membrane-bound, single crystal of biological magnetite (Fe3O4) or greigite (Fe3S4). Magnetosome chains orient single cells in the geomagnetic field and allow environmental positioning. Recent work on the genetics of biomineralization in magnetotactic bacteria (MB) has shown that both the greigite and magnetite genetic pathways share a common origin, supporting an earlier suggestion that the biochemistry of magnetotaxis is monophyletic.

Small subunit RNA sequence data from hundreds of extant MB are consistent with the origin of magnetotaxis within the Bacterial domain postdating the separation of stem-group cyanobacteria, but preceding radiation of the Proteobacteria (including the mitochondrial ancestor). We propose that the free-living mitochondrion ancestor was a magnetotactic bacterium. This hypothesis presents attractive implications for adopting cytoskeletal framework throughout the eukaryotic cell, for explaining the presence of magnetosomes throughout the Eukaryotes, and for justifying the demonstrated ability of the bacterial MagA protein to induce magnetite biomineralization in mammalian cells. The radiation of the Eukaryotic Domain of Life would therefore restore balance to the carbon cycle.

Keywords: Great Oxygenation Event, Cyanobacterial Evolution, Lomagundi Event, Mitochondrial Evolution, Magnetotactic Bacteria, Sedimentary Manganese

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(May 19-24 2013 at Makuhari, Chiba, Japan)

BAO01-12 Room:301A Time:May 21 15:00-15:15

STEM observation of graphite from 3.8 Ga Isua Supracrustal Belt

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Graphite is known to occur in the 3.8 billion years old Isua Supracrustal Belt (ISB) of western Greenland, and 13C-depleted graphite from sedimentary rocks of the ISB have been interpreted as traces of early life. The unequivocal documentation of biogenicity for graphite is complicated by the possibility of secondary graphite precipitation from metamorphic or igneous fluids and the difficulties in distinguishing biogenic from secondary graphite.

Graphite in meta-sedimentary rocks and carbonate veins in ISB is studied by STEM and Laser-Raman spectroscopy. Previous studies proposed that graphite in meta-sedimentary rocks are biogenic in origin, and others are chemical precipitates from CO2-rich fluids. STEM observation of graphite in meta-sedimentary rocks indicated many unique textures, resemble to carbon nano-tube. On the other hand, graphite in veins show sheet-structure-dominated features. Laser-Raman analyses indicate that sedimentary graphite recorded the peak metamorphic temperature. Graphite in veins showed lower temperature than that of the peak metamorphism. Those data comprehensively provide more evidence of biogenic graphite that differ from non-biogenic graphite in ISB.

Keywords: STEM, Raman

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Origin of life: Source rocks for the origin and evolution of life

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One of the key factors for the origin and evolution of life is a nutrient supply which is derived from rocks. Life cannot be synthesized under nutrient-free conditions in an atmosphere as shown in the famous experiments of Miller (1953). For the beginning of life, three components are essential; (1) C (carbon)-centered sugar for fuel, (2) P (phosphorus)-centered metabolism, and (3) N (nitrogen)-centered information coded by basic pairs (DNA). Among them, P (negative ion), which is a centered nutrient coupled with K (positive ion), plays a critical role in metabolic activity. Can those nutrients be derived from any kinds of rocks on the Earth? The answer is, yes, but only three kinds of rocks as follows

(1) Granite: Granite can be formed by two-step extractions of nutrients: partial melting of mantle peridotite at a mid-oceanic ridge followed by partial melting at a subduction zone, either by slab melting or re-melting of lower mafic crust generated by partial melting of a mantle wedge. The major nutrient elements, such as P and K, are large ion lithophile elements (LILE), and hence, difficult to be bound into major mantle minerals. Plate tectonics increases the volume of calc-alkaline rocks such as TTG (tonalite-trondhjemite-granodiorite) or andesite and dacite at subduction zones through time.

Granitic rock was absent when a magma ocean was consolidated at 4.5Ga. In the Hadean, the major rock source for nutrient supply was not granite, but rather presumably the primordial continents.

(2) Primordial continents (Anorthosite with KREEP basalts): Primordial continental material is the second candidate for the source of nutrients. No remnants of those continents remain on the modern Earth (i.e., no Hadean rocks are left). Understanding of the primordial continent is developed through the geology of the Moon, and also from the concept of giant impact. The surface of Moon is covered by 50 to 70 km-thick anorthositic crust with local cover and dikes of KREEP (Potassium, Rare Earth Elements, and Phosphorus) basalt composition, and presumably underplated by KREEP-like rock types beneath the anorthositic continent. Both rock units have been interpreted as the final residue of magma ocean when the Moon was formed by the giant impact that led to the formation of the early Earth, where Mars-sized protoplanets collided with each other. If the giant impact theory is correct, the Earth must have been completely molten even up to the core. During the gradual cooling of the Moon and the Earth, the final liquid remained near the surface, forming the buoyant anorthositic crust, covered or underplated by KREEP magma similar to that observed on the Moon.

(3) Carbonatite: Carbonatite has only a single step of fractional melting of mantle peridotites under the cratons with an extremely small degree of melting. The selective removal of melt to form considerable amounts of nutrients under the sub-cratonic mantle creates carbonatite magma enriched in nutrients with highly volatile incompatible elements such as H_2O and CO_2 (more than 80% are volatiles). Nutrients concentrate into melt, depending on the degree of melting. Peridotite contains P=50 and K=240 (all values in ppm hereafter), but 100 times concentration of P=4495-3273 and 200-300 times of K=56118-68902 are seen in carbonatite. In general, the nutrient abundance is ideal for carbonatite, except for the U abundance. Carbonatite plays the role of milk-like materials to grow life. However, it may also function like an atomic-bomb magma to cause local mass extinctions, as well as resultant promotion of genome mutation by internal radiation through food chains.

Japan Geoscience Union Meeting 2013
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BAO01-14 Room:301A Time:May 21 16:15-16:45

JAMP (Japan Astrobiology Mars Project): Search for Microbes on the Mars Surface with a Fluorescent Microscope.

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Introduction: Among the planets and giant satellites in our solar system, the characteristics of Mars are most similar to those of Earth. This suggests that the life similar to terrestrial life may arise and survive on Mars.

Here we propose a new life detection project on Mars within the scope of MELOS (Mars Exploration with Lander Orbiter Synergy), to search for methane-oxidizing microbes by fluorescence microscopy [1]. We propose to search for cells from a depth of about 5 - 10 cm below the surface, which is feasible with current technology. Microscopic observation has the potential to detect single cells. The subsequent anal-ysis of amino acids will provide the information need-ed to define the origin of the cell.

Survivability of Life in the Mars Environment: Physical and chemical limits for terrestrial life have been major foci in astrobiology [2], and are summa-rized in ref. [1]. Combining the environmental factors, anywhere in the Martian environment where we can find the three components, water molecules, reducing compounds and oxidative compounds could be an en-vironment where life can be sustained for long periods of time, if other factors such as temperature, pressure, UV and other radiations permit.

Methane Oxidizing Bacteria on Earth: Recently, a microbial consortium that is capable of using manga-nese (birnessite) and iron (ferrihydrite) to oxidize me-thane has been predicted in marine methane-seep sed-iments in the Eel River Basin in California [3]. Thus, there are several mechanisms of methane oxidation carried out by Bacteria and Archaea on Earth, and pos-sibly on Mars.

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Keywords: Mars, microbes, fluorescence microscope, Mars exploration, Astrobiology

BAO01-15 Room:301A Time:May 21 16:45-17:00

Amazonis and Elysium basins and Their Link, Marte Vallis (AME), Tharsis/Elysium Corridor, Mars

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The geologic provinces of Mars, as identified through a synthesis of geologic, paleohydro-logic, topographic, geophysical, spectral, and elemental information [1], are windows into its evolution, with the youthful province, the Tharsis/Elysium corridor [2-4], recording hydrologic, tectonic, and volcanic activity, including fissure-fed eruptions and shield-volcano field development, within at least tens of millions of years.

Geologically recent activity in the Tharsis/Elysium corridor region is particularly high-lighted in the Amazonis and Elysium basins and their link, Marte Vallis (hereafter referred to as AME). A youthful shield-volcano field with at least seven gentle sloping shield volcanoes and fissure-fed vent structures have been identified, mapped, and characterized in the western part of the Elysium. In addition, the lava flows on and near the margins of the shield volcanoes display crenulated lava flow margins, possibly marking lava-water-ice interactions. Both the shield volcanoes and pristine lavas located within AME, which are marked by a paucity of relatively small (~few-km-diameter) superposed impact craters and modified by faults and fractures and valleys, point to geological and hydrological activity on Mars in recent geologic time, making AME a significant target for future reconnaissance, including testing the hypotheses of whether Mars is geologically, hydrologically, and biologically active.

Specifically, the following questions might be addressed through international reconnaissance missions to AME, which would include instrument suites with optimal geologic, geochemical, geophysical (including seismic), environmental, and biological capabilities, including whether Mars: (1) is geologically and hydrologically active, (2) contains salty groundwater and magma at relatively shallow depths, (3) has sustained elevated heat flow, (4) records seismic activity, and (5) comprises fossilized and/or extant life.

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Current status of preparation of TANPOPO mission and investigation of survivability of microbes in space

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Microbes have been collected from high altitude using balloons, aircraft and meteorological rockets since 1936, even it is not clear how those microbes could be ejected up to such high altitude. Spore forming fungi, spore-forming Bacilli, and Deinococci (e.g. *Deinococcus aerius* and *Deinococcus aetherius*) have been isolated in these experiments. If microbes could be found even at the higher altitude of low earth orbit (400 km), the fact would endorse the possibility of interplanetary migration of terrestrial life.

For the origin of life on Earth emerged within a short period after the end of heavy bombardment, Panspermia hypothesis was proposed. Recent the reports on the possible fossils of microbes in the Martian meteorite promote the debate on the possible existence of extraterrestrial life, and interplanetary migration of life as well.

On the other hand, it is the question where precursors of materials such as protein and nucleic acids came from in the era of "chemical evolution" on the Earth? Recent studies suggest that the some of such organic compounds were created in space. Then, they reached the surface of Earth via meteorites, cosmic dusts, and so on. Avoiding contamination of terrestrial materials from the extraterrestrial materials is quite important issues for the analysis of extraterrestrial materials. Capturing such extraterrestrial materials before falling down on the surface of Earth might be one of possible solutions.

We have proposed a mission, named TANPOPO, to examine possible interplanetary migration of microbes, and organic compounds at the Exposure Faculty of Japan Experimental Module (JEM) of the International Space Station (ISS). The Tanpopo mission consists of six subthemes ? capture of microbes in space, exposure of microbes in space, capture of organic compounds in space, exposure of organic compounds in space, measurement of space debris at the ISS orbit, and evaluation of ultra low-density aerogel special for the TANPOPO mission.

Ultra low-density aerogel will capture micrometeoroid and space debris. Particles captured by aerogel will be analyzed from biological, chemical, and meteorological aspects.

In addition to particle-capture on ISS, we also proposed direct exposure experiments of microbial cell aggregates that might protect the microbes themselves from UV and cosmic rays. Deinococci (*Deinococcus radiodurans*, *D. aerius*, and *D. aetherius*), terrestrial cyanobacteria, and fungi are under consideration for space exposure. Amino acids and complex organic compounds that can be formed in space are also planed for space exposure.

In this paper, we overview the TANPOPO mission and discuss the current status of experiments related to the microbe existence/survival set for this mission.

Keywords: Panspermia, Space exposure, Origin of life

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BAO01-17 Room:301A Time:May 21 17:15-17:30

The sub-millimeter-sized aggregated deinococcal cells could be shield from solar UV

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To investigate the interplanetary transfer of life, numerous exposure experiments have been carried out on various microbes in space since 1960s. The results suggested that microbe spores might survive for a long period if the spores are shielded from intense solar radiation [1]. In the Tanpopo mission, we have proposed to carry out the experiments on capture and space exposure of microbes at International Space Station (ISS) [2]. Microbial candidates for the exposure experiments in space include *Deinococcus radiodurans*, *D. aerius* and *D. aetherius*. We have examined the survivability of *Deinococcus* spp. under the environmental conditions on ISS in orbit (i.e., long exposure to heavy-ion beams, temperature cycles, vacuum and UV irradiation). Among the space environmental factors, solar UV is most lethal to microbes, and damage is caused by the absorption of UV by DNA [3].

In this report, we examined the effect of solar UV radiation (172 nm, 254 nm and 280?315 nm respectively) on the deinococcal cell aggregates with different thicknesses to determine whether the size of the cell aggregate influences the cell survivability. Though the cells in thin layers of aggregates were killed by UV radiation, large number of cells survived the radiation when the cell layer was thick. The similar trend of survivability was observed for other UV range. Supposing that the aggregates are sphere, the diameter of the aggregate that is sufficient to shield the cells in the inner layer from solar UV radiation is 200 micrometer for *D. radiodurans*, 850 micrometer for *D. aerius*, and 700 micrometer for *D. aetherius*. We propose the microbial cell aggregate as an ark for the interplanetary transfer of microbes, and name it the 'masspanspermia' hypothesis.

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Keywords: Panspermia hypothesis, Space exposure experiments, Deinococcus, Cell aggregation, Massapanspermia hypothesis

BAO01-18 Room:301A Time:May 21 17:30-17:45

Restricting the amino acid usage of a resurrected ancestral protein

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It is common among life on Earth that proteins are composed of 20 or nearly 20 kinds of amino acids. However, it is uncertain that, from the standpoint of astrobiology, proteins are always composed of the 20 kinds of amino acids. Even for the evolution of proteins on Earth, it has been argued that primordial proteins that existed before the last universal common ancestor involved less than 20 kinds of amino acids (Crick, 1968). Given simpler protein synthesis system, the primitive proteins, which might have comprised a reduced set of amino acids, must have had a sufficiently adequate structure for functional interactions and catalysis. To address this issue experimentally, we used the protein simplification engineering (Akanuma et al., 2002) to examine whether a protein composed of less than 20 types of amino acids can retain its stable structure and biological function. To this end, we first resurrected several ancestral proteins and then restricted the amino acid usage of a resurrected protein to a reduced amino acid set.

As the model protein, we chose a house keeping enzyme, nucleoside diphosphate kinase (NDK). Because extant genes are evolutionary descendants of ancient genes, ancestral sequences of a particular protein can be inferred by comparing extant homologous protein sequences. Along this line, we first inferred several ancestral amino acid sequences of NDK by phylogenetic analysis of the extant homologous sequences. The inferred sequences were then genetically reconstructed. One of the reconstructed protein, Arc1, is very thermally stable (unfolding temperature = 113oC) and shows catalytic efficiency similar to those of the modern NDKs.

It is currently impossible to infer amino acid sequences that existed before the last universal common ancestor. Therefore, using Arc1 as the starting molecule, we reconstructed a reduced amino acid set variant, Arc1-s2, in which Met, Gln, Lys, Tyr and Asn were replaced by other amino acids. Because cysteine is absent from Arc1, Arc1-s2 consists of only 14 amino acid letters. Arc1-s2 retains thermal stability similar to that of Arc1; whereas, no detectable level of catalytic activity was observed for Arc1-s2. Therefore, the fourteen amino acid types are sufficient to encode a thermally stable protein but more amino acid types would be required for its function. To reevaluate the individual contributions of the 20 amino acid types to the stability and activity of Arc1, we reconstructed 19 Arc1 variants in which one of the 19 amino acid types was all replaced by other amino acids. The result will be also present in the meeting.

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