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

BAO01-01 Room:502 Time:April 28 09:00-09:15

Superflares on Solar-Type Stars

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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.

Keywords: Stellar flare, Solar flare, Habitability, Evolution

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Survey Observations of A Glycine Precursor, Methylenimine (CH2NH)

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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.

Keywords: Origin of Life, Chemical Evolution, Interstellar Medium, Glycine

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BAO01-03 Room:502 Time:April 28 09:30-09:45

Formation, alteration and delivery of interstellar organics: Verification with experiments on ground and in space

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As a wide variety of organic compounds have been found in meteorites and comets, their relevance to the origin of life is discussed. Many kinds of amino acids have been identified in extracts of carbonaceous chondrites, their origin is controversial. Possible carriers of organic compounds to the Earth were meteorites, comets and interplanetary dust particles (IDPs). It is said that IDPs could deliver organics more safely than meteorites and comets, the nature of organics in IDPs are little known since they have been collected usually in terrestrial biosphere. In addition, IDPs are directly exposed to cosmic and solar radiation, which might destroy organics in IDPs.

When possible interstellar media (a mixture of carbon monoxide or methanol, ammonia and water) was irradiated with high-energy particles, amino acid precursors were formed in high energy yields. We are planning to irradiate possible interstellar media with high energy heavy ions from a newly developed Digital Accelerator in KEK to confirm it. It suggested that amino acid precursors could be formed in interstellar space in prior to the formation of the solar system. Before the incorporation of interstellar organic compounds into comets or parent bodies of meteorites, they could be altered with high energy photons from the yound Sun. Soft X-rays irradiation of simulated interstellar organics resulted in the formation of hydrophobic compounds as seen in comets.

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: Capture experiments and exposure experiments. In the exposure experiments, organics and microbes will be exposed to the space environments to examine possible alteration of organic compounds and survivability of microbes. Selected targets for the exposure experiments of organic compounds are as follows: Amino acids (glycine and isovaline), their possible precursors (hydantoin and 5-ethyl-5-methyl hydantoin) and complex precursors (CAW) synthesized from a mixture of carbon monoxide, ammonia and water by proton irradiation. In capture experiments, we will collect space dusts by using ultra-low density silica gel (aerogel), and will analyze them after returning them to the Earth. Amino acid enanthiomers will be analyzed after HF digestion and acid hydrolysis, as well as characterization of complex organic compounds in space dusts. The mission is planned to be started in 2015.

Keywords: origins of life, interstellar organic compounds, cosmic rays, interplanetary dust particles, Tanpopo Mission, particles irradiation

BAO01-04 Room:502 Time:April 28 09:45-10:00

Polymerization of methionine: Ignition of sulfur metabolism?

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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.

Keywords: prebiotic, methionine, peptide, sulfur

BAO01-05 Room:502 Time:April 28 10:00-10:25

Formation of extraterrestrial oceans: Cradles of life

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As one of research groups on "Astrobiology in the Solar System" (a proposal submitted to MEXT), our group will study the origin of icy satellites around giant planets, and the origin and evolution of the interior ocean(s) of those icy bodies and their universality. Outside the so-called snowline of H_2O, the mass of protoplanets could be large enough to collect surrounding gas rapidly to form massive gaseous giant planets. Icy satellites would have been formed or trapped by the circumplanetary gas disks around giant planets. In multisatellite cases, orbital resonances may stabilize satellite migration and tidal dissipation would provide heat for sustaining interior oceans. Even when surface temperature is lower at a further distance from the sun, additional ice component (NH_3, CH_4, CO, etc.) would decrease the melting temperature. As a result, the more extended condition for presence of liquid water can be considered in comparison with the conventional habitable zone (with surface water).

Keywords: icy satellites, habitability, interior ocean, habitable zone, gas giant planets, origin of planetary systems

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BAO01-06 Room:502 Time:April 28 10:25-10:40

Tanpopo: Astrobiology Exposure and Micrometeoroid Capture Experiments - Experiments at the Exposure Facility of ISS-JEM

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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.

Keywords: Panspermia hypothsis, Microbes, Organic compounds, Aerogel, Space exposure experiments

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BAO01-07 Room:502 Time:April 28 11:00-11:25

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

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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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Keywords: Martian Magnetofossils, Rock Magnetism, Panspermia, Carbonate

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BAO01-08 Room:502 Time:April 28 11:25-11:40

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

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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.

Keywords: Komatiite, ore, submarine, Abitibi, microbe

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BAO01-09 Room:502 Time:April 28 11:40-12:05

Microbial community development in deep-sea hydrothermal vents in the Earth, and the Enceladus

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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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Light absorption and energy transfer in photosynthesis: Toward extending our current biosignatures

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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

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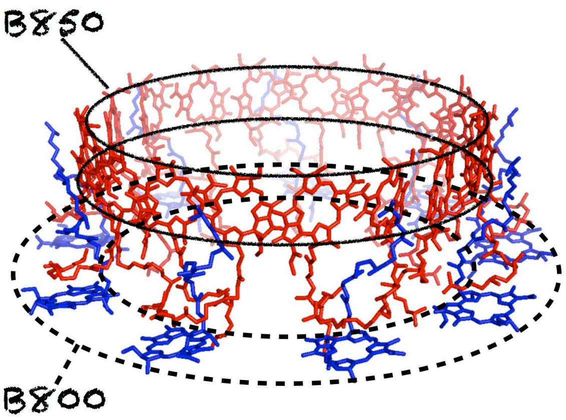

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BAO01-11 Room:502 Time:April 28 14:15-14:30

Ancient Habitable-Trinity Mars and Future Targeting of potential Signs of Life

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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.

Keywords: Habitable Trinity, potential signs of life

BAO01-12 Room:502 Time:April 28 14:30-14:55

Origin of life component of the Earth

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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.