ELSI 3rd international symposium
"Life in the Universe"
- List of abstracts for poster presentations –

Day 1 (Tuesday, January 13, 2015) - Planets as Cradles of Life

P1-01 Jennika Greer

Pre-3.78 Ga sedimentary protoliths in the Inukjuak Domain, northern Quebec (Canada)

The oldest volcano-sedimentary successions, locked in deformed gneiss terranes (supracrustal belts), are the only direct archives of Earth's surface zone at the time of life's emergence. Thorough field studies and laboratory analyses must be used to deduce protolith, emplacement age(s) and subsequent deformation. One such example is the Eoarchean (ca. 3750-3780 Ma) Nuvvuagittuq supracrustal belt (NSB), discovered in 2001 on the eastern shore of Hudson Bay in northern Québec. The NSB is one of a dozen or so km-scale supracrustal enclaves within the Innukjuak domain of the northwest Superior province. Dominantly amphibolites, these diverse and variably-deformed supracrustals are surrounded and intruded by several generations of tonalite-trondhjemite-granodiorite (TTG) gneisses. The TTGs imparted metamorphic overprints on the NSB beginning at ca. 3750 Ma. Previous work also documented a ca. 3650 Ma tonalitic gneiss at the margin of the NSB fold belt, as well as rocks of the so-called "Boizard suite", a body of ca. 2700 Ma granitoid gneisses that volumetrically dominate the Innukjuak domain. New geochemical and U-Pb zircon geochronological data are presented for these gneisses coupled with data from a previously undated but locally significant gneiss enveloping all supracrustal enclaves termed the "Voizel suite". The central tonalitic gneiss (CTG), located at the core of the NSB, hosts mainly ca. 3660 Ma zircons. Outside the NSB, Voizel rocks are the principal enclosing gneiss for other supracrustal enclaves such as the newly discovered (2012) Ukalik Supracrustal Belt, which is as old (or even older) than the NSB. Voizel igneous zircon cores cluster in age about 3550 Ma, some 130 Myr younger than the CTG. The Boizard suite contains inherited zircon cores up to 3700 Ma with ca. 2700 Ma overgrowths. A tonalitic gniess cross-cutting amphibolites from the USB, and within Voizel, yielded a maximum concordant zircon age of 3653±8 Ma; it may be cogenetic with the CTG.

P1-02 Ryoichi Nakada

Cerium stable isotopic fractionation as a potential paleo-redox proxy

The cerium (Ce) anomaly observed in rare earth element (REE) patterns has been used to estimate the redox state of paleo-marine environments. Cerium is unique in that it forms tetravalent cations under oxic conditions, in contrast to the other REEs that occur in a trivalent state. This characteristic leads to anomalously high or low Ce concentrations, relative to neighboring REEs. However, the use of Ce anomalies as a redox proxy is still a matter of contention. This study shows the potential of Ce stable isotope ratios to act as a more precise redox proxy. Our results reveal a progressive enrichment in heavy Ce isotopes in consecutive formations of iron (Fe) and manganese (Mn) precipitate from hot spring water, without any associated change in REE patterns. We have also undertaken isotopic analysis of Ce adsorbed on marine ferromanganese deposits, which also reflect redox conditions of their formation environment. These observations demonstrate that Ce stable isotope ratios yield more quantitative information regarding redox state than REE patterns alone. We thus suggest that this novel proxy can be successfully utilized to reconstruct marine redox state especially from slightly oxic to highly oxic conditions.

P1-03 Nigel M Kelly

Impact history of the inner solar system from (U-Th)/He geochronology of lunar and meteoritic zircon

Uncertainties over current radiometric ages from lunar rocks and impact melts, and debates about the meaning of age components in meteorites, limit our ability to confidently characterize the impact history of the inner solar system. For example, controversy persists between competing models for the rate of decline of impact flux to the inner solar system. Implementing new, more thermally-sensitive radiometric systems will provide a better means to document the timing and extent of impacts. Our collection of the "sampled solar system" consists of rocks from the Moon, Mars and asteroid belt that were thermally affected by impacts. Any discussions of the habitability and persistence of an early biosphere in the face of primordial impact history as recorded on the Moon, requires better geochronological input to new dynamical models for the origin and evolution of this impact flux. Our research on lunar impact-melt breccia samples integrates existing U-Pb ages of pre-impact lunar crust with new low-temperature (U-Th)/He zircon thermochronometry from the same grains. He-4, produced during the decay of U and Th, closes to diffusion from zircon at between ~220 and 140°C. This closure temperature and the susceptibility of zircon to resetting during subsequent thermal events, is highly dependent on radiation damage in the zircon grain. More damaged grains are more susceptible to He loss during lower temperature thermal events than less damaged grains, giving the potential to record multiple impact events of differing energy in a single sample set. Initial research is focused on characterization of existing radiation damage in lunar zircon grains as a guide to resetting potential during past impacts. Zircon crystallinity is being using laser micro-Raman and electron backscatter diffraction analysis. These qualitative to semi-quantitative data will be related directly to U+Th concentrations in the grains and enable robust interpretation of He-age spectra.

P1-04 Kazumi Yoshiya

In-situ iron isotope analysis of pyrite and organic carbon/nitrogen isotope ratios from the Middle Proterozoic sediments, McArthur Basin, Northern Australia

Oxygenation of Earth's surface is deeply linked to evolution of life. Independent evidence suggests that the Earth's atmospheric oxidation state is increased in two steps: (1) from 2,400 to 2,300 million years ago, and (2) around 600 million years ago (Holland, 2002; Holland, 2006). In contrast, the ocean was mostly reducing during the Archean, whereas the Phanerozoic was as oxygenated as it is now. Compared with Archean and Phanerozoic time, the redox status of middle Proterozoic (1.8-1 billion years ago) ocean remains little known. Canfield considered that the middle Proterozoic deep ocean was globally sulfidic condition (Canfield, 1998). On the other hand, Planavsky and others considered that deep-ocean was globally iron-rich anoxic condition, and sulfidic conditions are restricted to biologically productive ocean margin and restricted marginal basin (Planavsky et al., 2011). Here we show iron isotope analysis of individual pyrite grains and whole rock carbon/nitrogen isotope analyses of middle Proterozoic sediments, mainly mudstones and black shales, from four drillcore samples (Mount Young 2, McArthur River 2, Urapunga 4 and 5) in McArthur Basin, Northern Australia. Pyrites from the Wollogorang Formation of the Tawallah Group show the wide variation of δ^{56}Fe values from -2 to +2 ‰. It suggests that the occurrence of partial oxidation, so their depositional environment of the Wollogorang Formation was ferruginous condition. δ^{15}NTN values of the black shale in the Wollogorang and Barney Creek formations are from +4 to +7‰, relatively high values. The high δ^{15}NTN values suggest the occurrence of partial denitrification in the water-column. δ^{15}NTN values of black shale in the Wollogorang and Barney Creek Formations suggested that middle proterozoic sulfidic condition did not persist for long periods as previous studies insisted.

P1-05 Louis Lerman

Global Organic Weather Cycles and the Origin of Life: Planetary-Scale Infrastructures for Prebiotic Chemical Evolution on Terrestrial-like Planets

Just as the biochemistry of contemporary organisms can be viewed as a 'fossil' record of biogenesis, so the geochemical physics of the contemporary earth is an indicator of the self-organizing dynamic processes underlying prebiotic chemistry on any Earth-like planet. These insights flow from an understanding of water at the scale and perspective of its chemical physics in geologically realistic locally non-equilibrium environments. Mechanical disturbance of an air-water interface results in the Rayleigh-Taylor instability, which can be meta-stabilized by polar organic surfactants driven by surface free energy considerations. This leads directly to the creation of a complex planetary-scale hydrological cycle: a generalization of the terrestrial bubble-aerosol-droplet cycle modulated by the geological boundary conditions of the extraterrestrial body in question. Accompanying these conventional hydrology cycles are local 'organic weather cycles'. The existence of subsets of these cycles, both weather and organic self-organization, is likely even if surface waters were of such limited distribution as short time-scale lakes and intermittent turbulent flows. The hypothesis of the fundamental role played by this bubble-aerosol-droplet cycle offers the potential to overcome a number of stumbling blocks in the current field of prebiotic chemistry, addressing the problems of selectivity, concentration, and stabilization of organic products in prebiotic chemistry. It offers non-equilibrium heterogeneous chemical processes different from conventional solution chemistry, couples a supply of mechanical free energy to these chemical processes, and enables condensation reactions through the creation of relatively non-aqueous chemical environments within an aqueous medium. Taken together, the bubble-aerosol-droplet cycle provides a natural macroscopic framework for the microscopic realization of the majority of specific chemical model environments developed by others.

P1-06 Shinnosuke Aoyama

Microbial activity below Archean seafloor constrained by quadruple sulfur isotopes analysis of pyrite grains in ca. 3.5 Ga basalts from Pilbara Craton, Western Australia

Microbial sulfate reduction is one of the most ubiquitous metabolisms on Earth [Canfield, 1998]. In modern environment, it is well known that microbial sulfate reduction takes place below seafloor [e.g. Kallmeyer et al., 2012]. Aoyama et al. [2014] showed microbial sulfate reduction takes place not only in quiescent seafloor (i.e. non-hydrothermal), but also in active hydrothermal system. On the other hand, the oldest evidence of microbial sulfate reduction has been reported from ca. 3.5 Ga Dresser Formation, Western Australia by using quadruple sulfur stable isotopes analyses of sulfate and sulfide minerals related to hydrothermal environment [Ueno et al., 2008; Shen et al., 2009]. However, the isotopic compositions of sulfides and sulfate minerals through history show small isotopic fractionation (~20‰) before the rise of oxygen (c. 2450 Ma), possibly because of low sulfate concentration in the Archean seawater (<200 μM) [Habicht et al., 2002]. Microbial sulfate reduction below Archean seafloor might have yield larger sulfur isotopic fractionation owing to enhanced sulfate concentration. In order to test this scenario, we analyzed quadruple sulfur isotopic compositions of pyrite grains (from 10 to 40 μg) of seafloor basalts. For studying isotopic variation within sample, we used newly developed micro-fluorination technique.

P1-07 Joseph G O'Rourke

Powering Earth’s dynamo with magnesium precipitation from the core

Magnetic fields are likely important to planetary habitability. Before speculating about the potential for dynamo action throughout the universe, the history of Earth’s global magnetic field, which arises from vigorous convection within the liquid outer core, must be understood. Paleomagnetic evidence reveals that the geodynamo has operated for at least 3.4 billion years, placing constraints on Earth’s formation and evolution. Available power sources in standard models include compositional convection (driven by the solidifying inner core’s expulsion of light elements), thermal convection (from slow cooling), and perhaps heat from the decay of radioactive isotopes. However, recent first-principles calculations and diamond-anvil cell experiments indicate that the thermal conductivity of iron is two or three times larger than typically assumed. This suggests a paradox: a large increase in the adiabatic heat flux implies that the inner core is young (less than one billion years old), but thermal convection and radiogenic heating alone cannot sustain the geodynamo. Here we show that the precipitation of magnesium-bearing minerals from the core can serve as an alternate power source. Equilibration at high temperatures in the aftermath of giant impacts allows a small amount of magnesium (one or two weight percent) to partition into the core while still producing the observed abundances of siderophile elements in the mantle. Transport of magnesium from the cooling core to underplate the mantle is an order of magnitude more efficient per unit mass as a source of buoyancy than inner core growth. Earth’s dynamo can survive throughout geologic time even if radiogenic heating is minimal and core cooling is slow.

P1-08 Steeve Greaux

Seismic velocities of pyrolite and the structure of the Earth's mantle.

Comparison of seismic data with laboratory measured sound velocities in mantle minerals under high-pressure is a powerful tool toward constraining the mantle mineralogy. The composition and structure of the Earth's mantle if known would represent a major constraint on the thermal and dynamical evolution of our planet from its origin to the present state. Following recent studies we investigated the velocities of the pyrolite primary mineralogical model for the upper part of the mantle. Previous studies based their conclusions on velocities of HP minerals measured separately, sometime with different techniques. Here we measured directly the velocities of pyrolite aggregates synthesised at different pressures using a large volume press apparatus and a combination of ultrasonic and synchrotron radiation techniques. Our results showed a clear contrast in between the velocities of samples synthesized at 10 GPa and those made at 17 GPa in agreement with the Olivine-to-Wadseleyite transformation at ~14 GPa. Another velocity increase was also observed in situ at P higher than 20 GPa, which correspond to the formation of the Ringwoodite phase. The velocity gradients associated with those phase transformations are well consistent with PREM in the lowermost transition region but fail to explain its uppermost part especially at the 410 km depth discontinuity.

P1-09 Haruka Ozawa

High-pressure melting experiments on Fe-FeSi alloys

Earth's core includes substantial amounts of light elements in addition to iron and nickel. The principal light element must reproduce the density jump at the inner core boundary (ICB). Silicon is thought to be a plausible light element in the core, and the melting phase relations in Fe-FeSi binary system at the ICB pressure are of great importance. Theoretical calculations on the Fe-FeSi binary system suggested that the difference in Si content between the outer core and the inner core would be too small to satisfy the observed density jump at the ICB [Alfe et al., 2002 EPSL], which requires other light elements in addition to silicon. Here we experimentally examined partitioning of silicon between liquid and solid iron up to 127 GPa. High pressure and temperature conditions were generated in a laser-heated diamond-anvil cell. Chemical compositions of co-existing quenched liquid and solid Fe-Si alloys were determined with a field-emission-type electron probe micro-analyzer. We used Fe-Si alloys containing 6.5 or 9 wt% Si as a starting material. Chemical analyses on the recovered sample from 24 GPa with the bulk composition of Fe-9wt% Si demonstrated the coexistence of quenched Si-enriched liquid and Si-depleted solid. In contrast, silicon partitions preferentially into solid phase between 47 and 127 GPa, suggesting the starting composition (Fe-9wt% Si) lies on the silicon-rich part of the eutectic. These results indicate the eutectic composition shifts toward iron between 24 and 47 GPa.

P1-10 Shigehiko Tateno

Temperature and structure of the Earth's inner core

The Earth’s liquid core crystallizes to form the solid inner core with structural complexity, which is evident from seismic anisotropy. The structure and temperature of the constituent material is essential for deciphering the such observations, and thus, understanding the elastic and transport properties, and dynamics. These call for the knowledge of crystal structure of iron alloy forming the core and its melting temperature at high pressures. We study the phase relations of Fe, Fe-Ni alloy, and Fe-Si alloy, and melting temperature of pure iron in terms of high-pressure and temperature experiment. High-pressure and temperature behavior of the iron material is probed in situ by synchrotron X-ray in a diamond-anvil cell as a high pressure devise. Furthermore, the recovered sample was examined under FIB-SEM, FE-EPMA, and FE-TEM, our state-of-art analytical devises of ELSI.

P1-11 Matthieu Laneuville

Effect of a fractionated basal magma ocean on the Earth dynamo

After the Moon forming impact, the Earth was in a largely molten state. Subsequent impacts also helped create the conditions for efficient mixing. Metal-silicates fractionation that follows will produce density gradients at the base of the mantle. We show here that if these gradients are stable against convection, i.e., if a layer between the core and mantle has to cool through conduction, the core is able to retain primordial heat for a longer time than originally thought. This has large consequences on the Earth dynamo history.

P1-12 Hiroki Ichikawa

Hot plumes caused by transitions involving majorite

Influence of $MgSiO_3$ majorite on the mantle convection has been investigated by using 2-D numerical simulations incorporating stability field of majorite (Ichikawa et al., 2014). According to a recent first principles study (Yu et al., 2011), wadsleyite decomposes to an assemblage of majorite plus periclase with a large negative Clapeyron slope. Since stability field of majorite is limited to above ~2200 kelvin in a depth range of 500-660km for Mg_2SiO_4, very hot upwelling plumes are expected to be strongly influenced by the phase transitions related to majorite. These hot upwellings are occasionally observed in the simulations, even though the average temperature of hot plumes are far less than the stability field of majorite. The dynamics of these upwellings are modified by the release and the absorption of latent heat induced by the transitions as well as interruption of currents due to the large negative Clapayron slope related to majorite.

P1-13 Zhaodong Liu

Phase relations of $MgSiO_3$-Al_2O_3 system in Earth's lower mantle

Aluminum oxide (Al_2O_3) is present in about 4~5 mol% for the Earth's mantle compositions, e.g., pyrolite, piclogite and chondrite (Ringwood, 1966; Sun, 1982; Anderson, 1989; Irifune et al. 1986, 2007). In the Earth's lower mantle conditions, the Al_2O_3 is accommodated mainly in $(MgFe)SiO_3$ pervoskite (Irifune 1994), which is the most abundant mineral phase in this region (Ringwood 1975). The $MgSiO_3$-Al_2O_3 system is a basis system to understand lower mantle phase equilibria in a more complex composition, such as pyrolite. Phase relations of $MgSiO_3$-Al_2O_3 system have since been extensively studied using the multi-anvil devices with tungsten carbide anvils from upper mantle to the uppermost parts of lower mantle conditions (Irifune 1986, 1996; Kubo et al. 2000; Hirose et al. 2001; Akaogi et al. 2002), and also further constructed by theoretical calculation (Panero et al. 2006; Tsuchiya et al. 2008). The phase relation of $MgSiO_3$-Al_2O_3, especially toward the Al_2O_3-rich side, in the lower mantle conditions is still relatively limited. Recent technique development of sintered diamond anvils in multi-anvils apparatus allow us to achieve the high pressures and high temperatures conditions of Earth's middle lower mantle(Tange et al. 2008; Irifune et al. 2010; Ito et al. 2010; Yamazaki et al. 2014). Here, we further extend the phase relations of $MgSiO_3$-Al_2O_3 system between 31 GPa and 45 GPa at 2000K using multi-anvil apparatus with sintered diamond anvils. Aluminum oxide solubility in $MgSiO_3$ perovskite is increasing with the increasing pressure and temperature.

P1-14 Nao Cai

Dehydration of chlorite and formation of a new hydrous phase

Subducting slabs are supplying water into the deep mantle, so the stabilities of hydrous minerals under high pressure and high temperature are important issue to clarify the water transportation mechanism into deeper part of the Earth's mantle. Dense hydrous magnesium silicates (DHMS) have been well constrained in the $MgO\text{-}SiO_2\text{-}H_2O$ system, while few researches have been done in the $MgO\text{-}SiO_2\text{-}H_2O\text{-}Al_2O_3$ system under relatively high pressure (i.e. higher than 6 GPa). Here we conducted high pressure and high temperature experiments on natural chlorite. At 6 GPa 700°C, we found the coexistence of chlorite, pyrope and Mg-surssasite, while at 7 GPa and 800°C the chlorite decomposes into a new Al-bearing hydrous phase plus pyrope, chondrodite and fluid. This new hydrous phase has been reported at AGU fall meeting 2014 by Cai et al., which shows a quite unique structure among the mantle minerals in having an extraordinarily long c axis. The discovery of this new phase in the chlorite composition extends the stability region of hydrous phases in the subducting slabs, and may also open a new field on studying the structure of hydrous phases under high pressure. This new hydrous phase may play an important role in transporting water into the deep Earth along the subducting slabs.

P1-15 Koichiro Umemoto

Liquid iron alloys with light elements at outer core conditions by first-principles calculation

Since the density of the outer core deduced from seismic data is about 10% lower than that of pure iron at core pressures and temperatures (P-T), it is widely believed that the outer core includes one or more light elements. Although intensive experimental and theoretical studies have been performed so far, the light element in the core has not yet been identified. Comparison of the density and sound velocity of liquid iron alloys with observations, such as the PREM, is a promising way to determine the species and quantity of light alloying component(s) in the outer core. Here we report the results of a first-principles molecular dynamics study on liquid iron alloyed with different concentrations of sulfur and hydrogen, in order to clarify the effects of their impurities on the liquid density and sound velocity under outer core P-T conditions. We discuss the composition of the Earth's outer core based on a comparison of the present results with the PREM density and velocity profiles.

P1-16 Wei Du

Contribution of volatile rich material to the Earth's accretion

Heterogeneous accretion model that describes that growth and evolution of Earth in two different stages from volatile-depleted and volatile-rich material was revised based on ^{107}Pd-^{107}Ag and ^{182}Hf-^{182}W decay system (Nudds et al., 2010). A second stage accretion of volatile-rich chondrites, which has similar ^{107}Ag/^{109}Ag with the Earth's mantle, eliminates the conflict between Hf-W and Pd-Ag systematics. However, the exact percentage and the time sequence of this volatile-rich material accretion needs to be constrained and this result need to be consistent with the siderophile elements concentration in the Earth's mantle and the oxidation state of the Earth's mantle changes through the accretion process. Therefore, we performed experimental studied on Tagish Lake chondrite, a new type of volatile rich chondrite to different pressure and temperature conditions. Our target is to explore the possible time sequence of the addition of volatile-rich material to the Earth's growth and the water budge of the Earth at different accretion sequences, the accretion and the later impact.

P1-17 Vincenzo Stagno

Quasicrystals at HP-HT: implications for the redox conditions during planetary formation

Icosahedrite, $Al_{63}Cu_{24}Fe_{13}$, the first natural-occurring quasicrystal, has been recently discovered in the Khatyrka meteorite, a new CV3 carbonaceous chondrite. Its finding has raised fundamental questions regarding the effects that pressure and temperature might have on its stability. In addition, the presence of an AlNiFe alloy (steinherdtite) would suggest extremely reducing conditions during for the formation of this chondrite. Although several studies showed the stability at ambient temperature of synthetic icosahedral AlCuFe up to ~35 GPa, the simultaneous effect of temperature and pressure has been never investigated so far. We performed experiments at high pressure and temperature using both multi anvil and diamond anvil cell to better understand the origin and stability of Al-rich alloys and phase equilibria in the Al-Cu-Fe system. We carried out high-pressure experiments with in situ energy-dispersive X-ray diffraction experiments using multianvil device on synthetic icosahedral AlCuFe to explore possible temperature-induced phase transformations at pressures of ~5 GPa and temperature up to ~1700 K. Additional quench experiments were also performed to investigate decomposition and /or melting of $Al_{63}Cu_{24}Fe_{13}$ between 3 and 21 GPa and temperature of 1300-2000K. Additional experiments were carried out to test the stability of synthetic icosahedrite at pressures up to ~70GPa using in situ angle dispersive X-ray diffraction under quasi-hydrostatic conditions in diamond anvil cell with neon as pressure medium. Results showed the stability of i-AlCuFe phase at high pressure. In addition, an accurate structural analysis by single crystal X-ray diffraction of the recovered samples excluded the transformation of icosahedral AlCuFe quasicrystalline phase to possible crystalline phases. Preliminary results from quench experiments would suggest that the increasing pressure acts to stabilize the i-AlCuFe at higher temperatures.

P1-18 Hernandez-Resendiz Patricia

Study of chondrule formation mechanisms in chondrites from melts generated experimentally.

We will simulate the formation of chondrules by melting silicates (mainly olivine) with a 50W CO_2 laser in high vacuum conditions. We will measure the temperature during and after the formation of the artificial chondrules. We will comparate our melts with the natural chondrules that exist in chondrites with the purpose of determine the heating conditions of our melts that reproduce the features seen in natural chondrules.

P1-19 Shoji Ueta

Development of simulation code for impacts of small planetary bodies and estimate of the impact erosion

The evolution of atmosphere and ocean on the Earth is significantly influenced by the impact of small planetary bodies. The modified atmosphere and ocean could change the surface environment. The most realistic numerical simulations, Shuvalov (2009) and Shuvalov et al. (2014), used an Eulerian code and assumed only rock material as the target of impacts, not considering the oceanic erosion. In this study, we aim to develop an advanced numerical code for simulation of impacts of small bodies, assuming the target as rock and/or ocean. We employ a new Lagrangian hydrocode in Hosono et al. (2013), Density Independent Smoothed Particles Hydrodynamics (DISPH), and improve the code for such a simulation. For smaller calculational load and better calculational results, unequal-mass particles and equal-separation arrangement are used to construct the boundaries between the atmosphere and ocean/land. In the hydrostatic equilibrium tests, it is shown that we can change the mass of particles even in the range of 2000 times with DISPH to express quite different values of density. This result is a highly significant for us to simulate the impacts of small planetary bodies more realistically. In this work, we will also discuss the escape mass of atmosphere and ocean with the simulation of the impacts.

P1-20 Junko Kominami

Formation of Planetary Systems : Large Scale N-Body Simulations

Numerous planets and planetary systems have been found outside our Solar system. Before the finding of these exoplanets, formation theory of our Solar system had been investigated thoroughly and a standard formation theory was constructed. Many of the exoplanets and exoplanet systems are hard to explain using the standard theory for our Solar system. In addition, some unsolved problems still exist in the standard planet formation scenario explaining the Solar system. N-body simulation is a major tool for investigating planet formation theory. One of the reasons why there still exist some uncertainties is the restriction of number of N-body particles in the simulations. Standard model has been constructed using the results of simulations of narrow region of the disks. However, the inner region and the outer region of the disk have different physical properties. In order to construct a scenario applicable to a wider ranged region of planetary disks, N-body simulations with larger scale is required. We have developed a new code that can simulate large-scale N-body simulations on supercomputer K. Some recent results will be presented.

P1-21 Miki Nakajima

Origin of the Earth, Moon and exomoons

The giant impact hypothesis suggests that the Moon formed out of a partially vaporized disk created by a collision between an impactor and the proto-Earth. Three major models exist for this hypothesis: (a) standard model: a Mars-sized impactor hit Earth, (b) fast-spinning Earth model: a small impactor hit the rapidly-rotating Earth, (c) sub-Earths model: two half Earth-sized objects collided. Some of these models can explain several observed features, including the nearly identical isotopic ratios between Earth and Moon. However, it has not been clear if these models can explain other geochemical constraints, such as (1) ancient chemical heterogeneity of the Earth's mantle that likely survived the giant impact, and (2) some geochemical measurements that suggest the Moon did not lose significant amount of water (hydrogen) during its formation. Here, we show results from giant impact simulations and investigate whether the suggested models are consistent with these geochemical constraints. We show that the standard model is more consistent with the survival of the mantle heterogeneity than the other models. We also find that water loss from the Moon-forming disk is minor in all models. Therefore, the giant impact hypothesis is consistent with the measured lunar water abundance. Finally, we will discuss implications of our model for the formation of exomoons.

P1-22 Toshiaki Iitaka

Early Earth Simulator Project

"Early Earth Simulator Project" is introduced as a proposed project of a computer simulation program for the early earth evolution to form a Cradle of Life[1]. The simulation is to run on the so-called 'Post-K computer', the planned national flagship supercomputer of Japan as the successor of the 'K-computer'. The main feature of the simulation will be the theoretical prediction of material properties in extreme conditions, such as high temperature and high pressure, which is based on first-principles atomistic simulations. The results of the atomistic simulations will be augmented with existing results of laboratory experiments and phenomenological knowledge of geology, and will be input to the macroscopic program that simulates the global evolution of the early earth. The target of the simulation may include the formation of magma ocean, crust, mantle, water ocean and atmosphere as well as partition of elements in the early earth. The atomistic simulations may include the first principles molecular dynamics simulation of silicate melts, liquid and solid iron, minerals, and water in extreme conditions. The state of arts computational techniques such as massive parallel computation and order-N techniques for large scale calculation, multi-scale simulation, first principles prediction of crystal structure and reaction path, evaluation of solubility, quantum Monte Carlo methods, and extended ensemble methods of statistical mechanics. The project will have one year of feasibility study after the acceptance by MEXT. Proposal of simulations to be included, as well as discussion and criticism of the project, would be highly appreciated at the poster session.

[1] http://www.cms-initiative.jp/ja/events/20150116-post-k

P1-23 Takayuki Saitoh

Entropy core formation in cluster of galaxies with DISPH

Frenk et al (1999) carried out a comparison test of the formation of a cluster of galaxies using both Lagrangian particle codes and Eulerian grid codes. Although most of global features of the resultant cluster are very similar to each other, there is a systematic discrepancy in the entropy structure in the cluster of galaxies, i.e., that results with mesh codes showed a core structure in the cluster center and those with particle codes did not. We have developed a novel particle scheme, density independent formulation of smoothed particle hydrodynamics (DISPH), which solves a crucial weak point of the conventional (standard) SPH. We apply our scheme for the formation of the cluster of galaxies and find that the simulated cluster with our scheme shows an entropy core. The value of the core entropy is identical to those obtained by the recently developed a hybrid scheme of the Lagrangian and Eulerian grid schemes while it is about unity lower than those obtained by grid codes. Thus, we consider our scheme is a good alternative to the conventional SPH.

Day 2 (Wednesday, January 14, 2015) - Towards Universal Biology

P2-01 Yuko Sasaki-Sekimoto

Evolution of plant lipid metabolism during colonization of land

The colonization of land by plants was a key event to make the modern terrestrial environment habitable. During this process, an aquatic alga must have acquired adaptation systems to survive in the harsh terrestrial environments. To understand the process, we focused on an amphibious alga *Klebsormidium flaccidum* (Division Charophyta, Order Klebsormidiales), which has a simple body plan and form multicellular filamentous structures. Recently, we analysed the draft genome sequence of Klebsormidium (Hori et. al., 2014 Nature communications). The genome of this alga has intermediate properties between algae and land plants. It is interesting to note that it encodes several genes to synthesize wax components, which are important in tolerance to harsh land environments such as freezing and drought. We chemically analyzed the outer wax components of *K. flaccidum* in comparison with other land plants. We will discuss about the importance of the lipid metabolisms during land colonization of plants.

P2-02 Lewis M Ward

A Model for Rapid Oxidation of the Atmosphere Following Evolution of Oxygenic Photosynthesis Suggests Late Evolution of Cyanobacteria

Oxygenic photosynthesis—the ability to split water with sunlight—is the most important bioenergetic innovation in the history of life and it truly transformed our planet. It is widely accepted that the invention of oxygenic photosynthesis by Cyanobacteria resulted in the Great Oxidation Event (GOE) ~2.35 Gya, but it is debated whether this occurred immediately following the evolution of Cyanobacteria or whether they originated earlier in Earth history. The latter hypothesis involves a prolonged period in which oxygen production rates were insufficient to oxidize the atmosphere either due to redox buffering by reduced species in the atmosphere or oceans, or due to nutrient limitations for primary productivity. Here, we present ecological and geochemical models that suggest oxygenation proceeds geologically instantaneously upon evolution of oxygenic photosynthesis. This suggests that Cyanobacteria arose shortly before the GOE and that other explanations are necessary for geochemical evidence for "whiffs" of oxygen. This further suggests that the evolution of oxygenic photosynthesis is sufficient to develop an oxygenated atmosphere and therefore to support aerobic respiration, an essential step in the development of complex life.

P2-03 Kumiko Kihara

Toward to the genome analysis of the microorganisms living in a primitive environment

Given the fact that no life is built without genomic information, “the origin of life” can be rephrased as “the origin of genome.” The origin of genome, however, would not be simply inferred from the present genomes. One of the strategies to infer the origin of genome is to investigate genomes in the existing environments analogous to putatively primitive environments, where the origin of life might have occurred. It is expected that life in such an environment maintain original feature, while life in changing environments has evolved into more complicated and diversified forms. We have developed and performed "single cell genomics" for environmental samples containing uncultivable microbes, and this approach is applicable to the investigation of “primitive genomes” in extreme environments, such as serpentinite-hosted hydrothermal systems that have been hypothesized to be site of a biotic organic synthesis and habitats for the earliest microbial communities (e.g. Hakuba, Japan). We collected hot spring water in Hakuba district and that water samples containing microbial cells were loaded into a flow cytometer for separating them to single cells. Each single cell was directly subjected to whole genome amplification (WGA), using phi29 DNA polymerase. WGA samples were first analyzed to determine 16S rRNA gene sequence for taxonomic identification. Genome sequences of selected WGA samples were analyzed by using next-generation high-speed sequencers and bioinformatics techniques. Genomic and subsequent metabolic analyses of bacterial lineages in such an environment potentially will lead us to better understanding of the origin of genome, that is, the origin of life.

P2-04 Ken Kurokawa

MicrobeDB.jp: Developing an integrated Database for Microbes with Semantic Web Technologies

Microbes are essential for every part of life on Earth. Numerous microbes inhabit the biosphere, many of which are uncharacterized or uncultivable. They form a complex microbial community that deeply affects against surrounding environments. Metagenome analysis provides a radically new way of examining such complex microbial community without isolation or cultivation of individual bacterial community members. However, metagenome analysis is more complex than common genome analysis, because an analysis target is composed of enormous bacterial strains instead of a single strain. Moreover, the enormous amounts of sequencing data produced by next generation sequencers are difficult to effectively analyze using existing computational tools. To untangle the complexity of metagenome analysis, we have been developing a global microbial database integrated by microbe genomics and metagenomics database with semantic web technologies named “MicrobeDB.jp”.

P2-05 Arturo Rubio

Virtual Communities for Astrobiology divulgation

This Project offers an astrobiology divulgation proposal that takes advantage of the knowledge built trough the interaction of scientists, divulgation system and specific audience within the third environment (3E) in order to fulfill science divulgation main objective: establishing a link between the world of science and other worlds. To achieve this, I begin making a critical analysis of two different perspectives: The first one comes from the 3E, trough McKenzie's Wark Hacker's Manifesto which offers a cognitive tool, hacking, that establishes the construction of new planes of interaction within the virtual space between users from different knowledge communities. It configures itself as a principle of social innovation that may bring a humanized perspective into the 3E. The second perspective comes from the academy and belongs to Javier Echeverria. It is called Knowledege Republics. It´s main argument revolves around the importance of the cognoscent subject as an agent capable of introducing action principles, under an axiological notion, that promotes the inclusion of democratic and republican values to the practices within the 3E. From the analysis of these perspectives and trough the recognition of different levels of expertise from the users of the 3E, I have a constructed an intermediate proposal which is the projects guide, characterized by: a) its consideration to the multiculturality of the individuals involved in this divulgation proposal b) collaboration between diverse disciplines in the production of the information c) its free and unrestricted access d) guided by the needs of the original communities of the 3E users.

P2-06 Enrico Sandro Colizzi

Mutation-driven division of labour within Quasispecies

According to Quasispecies theory, high mutation rates limit the amount of information genomes can store (Eigen's Paradox), while genomes with higher degrees of neutrality may be selected even at the expense of higher replication rates (the "survival of the flattest" effect). Introducing a complex genotype to phenotype map, such as RNA folding, epitomizes this effect because of the existence of neutral networks and their exploitation by evolution, affecting both population structure and genome composition. We re-examine these classical results in the light of an RNA-based system that can evolve its own ecology. We find that populations evolving at high mutation rates structure themselves in a quasispecies-like fashion. Contrary to expectations, these quasispecies are characterized by a low degree of neutrality and have one master sequence. Importantly, individuals emerge which perform non-preconceived functionalities, crucial for the overall viability and stability of the system. However, they cannot be replicated, and therefore can be generated only by mutation of the master sequence or its viable offspring. In other words, the genome of the master sequence encodes the information of the entire ecosystem, whereas the decoding happens, stochastically, through mutations. Moreover, this solution quickly outcompetes strategies based on genomes with a high degree of neutrality. In conclusion, individually coded but ecosystem-based diversity evolves and persists indefinitely close to the Information Threshold.

P2-07 Matthieu Laneuville

Emergence of multicellularity from stochasticity

The transition from uni- to multicellularity is one of the major transition undergone by life on Earth. The reduction of propagule size required to generate a new individual improve resistance to deleterious mutations. In this project we design a minimal numerical model in order to understand what drives this transition. We find that stochasticity itself determines how many different species can be maintained for a given propagule size, and therefore how fit can a population be.

P2-08 Tetsuya Yomo

The Evolutionary Enhancement of Genotype-Phenotype Linkages

Genetic evolutionary mechanisms developed without accompanying regulatory mechanisms for the amounts of genetic material in protocells. When many copies of genetic material are present, inactive copies generated by mutations are not effectively excluded through phenotypic selection. We demonstrate a model of genetic evolution initiated with multiple copies of DNA inside artificial protocells. Despite the fact that the average number of DNA copies in each liposome was 6.4, DNA encoding active genes was maintained until the 16th selection round. Our experimental result indicated that genetic evolution can occur in the presence of multiple DNA copies. Most genetic material became junk code through gene mutations, and consequently the linkage between genotype and phenotype was enhanced through the associated decreases in active genetic material.

P2-09 Ryo Mizuuchi

An evolvable artificial cell model

The origin of life and the following evolution have been debated for ages. In our laboratory, we have addressed these puzzles from the point of "reconstruction". Several years ago, we constructed translation-coupled RNA replication (TcRR) system by combining an artificial genomic RNA encoding the RNA-dependent RNA polymerase (RNA replicase) and a reconstituted Escherichia coli translation system [1]. In this system, the genomic RNA replicates in the same way as life, through the translation of genetic information. Recently we expanded TcRR system to enable Darwinian evolution, one of the most remarkable abilities of life. We encapsulated TcRR system in a cell-scale lipid compartment, a water-in-oil emulsion which separates each RNA molecule and allow the competition in terms of growth. We repeated TcRR reactions using this system along with the manual fusion-division cycle of the compartment. After hundreds of cycles, the genomic RNA spontaneously evolved to replicate with more than 100-fold efficiency due to mutations introduced as replication errors [2]. Furthermore, we performed a similar experiment with the evolved RNA in a severer environment, where the concentration of ribosome was reduced. As a result, the genomic RNA adapted and evolved again in the changes environment, like life [3]. In long TcRR reaction, so-called parasitic RNA, a short RNA lacking the internal replicase-coding region yet retaining the terminal recognition sites, is spontaneously generated. Once replicase is translated from the genomic "host" RNA, the short parasitic RNA rapidly replicates, as long as replicase exists. Through the long-term TcRR reactions, we have found both the host and parasitic RNA could persistently coexist in the oscillating population, while evolving, which looked like cell-virus relationships.

[1]H. Kita et al., ChemBioChem, 2008, 9 (15) [2]N. Ichihashi et al., Nat. Commun., 2013, 4(2494) [3]R. Mizuuchi et al., ACS Synth. Biol., 2014, in press. DOI: 10.1021/sb5000884

P2-10 Yutetsu Kuruma

Construction of artificial cell membrane for the study of the origin and evolution of life

Lipid membrane vesicles are superior as a model cell membrane for the construction of artificial cell. In order to close more this model membrane to a real cell, it is very important to implement various membrane dynamics that can be observed on a living cell membrane. However, in general, to achieve these membrane dynamics only with lipid molecules is very difficult, therefore a number of hydrophobic membrane proteins, which undertake the biochemical functions, are required on the cell membrane. Knowing the essential membrane functions is important for the studying of the early stage of cellular life and, also, important to elucidate how the simple lipid membrane acquired a dozen of membrane functions such as channels, transporters, sensors, etc. So far, we have achieved various membrane functions on phospholipid membrane vesicles through synthesizing the responsible membrane proteins by gene expression. Particularly, we show some results in the construction of ATP synthase and Sec translocon (a membrane channel conducting the membrane insertion of protein). We are aiming to understand the emergence of cell membrane functions, through constructing these possible biofunctions that might exist in the early stage of cellular life.

P2-11 Jay G. Forsythe

Structural Investigations into the Prebiotic Origins of Peptides

For more than half a century there has been evidence that amino acids were present on the prebiotic Earth, either by endogenous formation or by delivery in meteorites. Nevertheless, the process by which amino acids were converted to peptides is still unclear. For an amide (or peptide) bond to form between two amino acids a water molecule must be removed, a process that is thermodynamically unfavorable in aqueous solution. Several potential mechanisms to circumvent this problem have been proposed, including chemical activation of amino acids, environmental cycling (e.g., wet-dry cycles), and chemistry at liquid-air interfaces. Using a mild environmental cycling model, we explored the plausibility of polyesters as precursors to polypeptides ("proto-peptides"). Alpha-hydroxy acids, found in both model prebiotic reactions and meteorites, readily form polyesters upon mild drying and heating. Using state-of-the-art ion mobility-mass spectrometry (IM-MS) and ion mobility-tandem mass spectrometry (IM-MS/MS) techniques, we obtained significant insight into structural elements of these polyester-based "proto-peptides." In particular, IM-MS/MS allowed us to determine residue sequences, distinguish structural isomers (e.g., linear vs. branched), and quantitatively measure gas-phase collisional cross sections. Using this information, we are searching for structural motifs and sequences that enable chemical evolution and/or self-replication, potentially bridging the prebiotic gap between amino acids and polypeptides.

P2-12 Norio Kitadai

Thermodynamic evaluation for the effects of pH and metal cations on the polymerization of amino acids

How and where did life on the Earth originate? To resolve that fundamental question, we first need to ascertain reactivity of biomolecules, and its response to changing environmental conditions such as temperature, pH, dissolved composition, oxidation state and mineral surface. Amino acids are building blocks of proteins, which are fundamental to life. Therefore, the synthesis and polymerization of amino acids have been a topic of many experimental and theoretical works. In this study, thermodynamic calculations were performed for the polymerization of Gly in the presence of various metal cations (Ag^{2+}, Al^{3+}, Cd^{2+}, Co^{2+}, Cu^{2+}, Fe^{2+}, Hg^{2+}, Mg^{2+}, Ni^{2+}, Pb^{2+} and Zn^{2+}) using reported complexation constants of metal-Gly (and Gly peptides) complexes. Gly was chosen because it is the simplest amino acids. Gly has been used as a model to examine effects of metal cations on the polymerization reactivity of amino acids in many experimental researches (e.g., Schwedinger and Rode, 1989; Eder and Rode, 1994). The pH ranges examined for Cd^{2+}, Co^{2+}, Cu^{2+}, Hg^{2+}, Ni^{2+}, Pb^{2+} and Zn^{2+} cover a wide pH region ranging from acidic ($\leq$ 3.0) to alkaline ($\geq$ 8.5). The effects of metal cations on the polymerization of other amino acids (e.g., Ala) were also discussed. It will be shown that metal cations inhibit Gly polymerization greatly in neutral to alkaline pH region. The negative effect becomes greater as the metal cation has a higher charge/radius ratio, and increases with higher concentration. Similar situation is expected to be observed for polymerizations of other neutral amino acids. These results indicate that, at least in thermodynamic point of view, aqueous solutions with concentrated heavy metal cations are greatly unfavorable for the polymerization of neutral amino acids in neutral to alkaline pH region.

P2-13 Hossein Shenasa

Generation of oligonucleotides under hydrothermal conditions by non-enzymatic polymerization

We previously reported that 5'-mononucleotides organized within a multilamellar lipid matrix can produce oligomers in the anhydrous phase of hydration-dehydration (HD) cycles. However, hydrolysis of oligomers can occur during hydration, and it is important to better understand the steady state in which ester bond synthesis is balanced by hydrolysis. In order to study condensation products of mononucleotides and hydrolysis of their polymers, we established a simulation of HD cycles that would occur on the early Earth when volcanic land masses emerged from the ocean over 4 billion years ago. At this stage on early Earth, precipitation produced hydrothermal fields characterized by small aqueous pools undergoing evaporation and refilling at elevated temperatures. Here, we confirm that under these conditions, the chemical potential made available by cycles of hydration and dehydration is sufficient to drive synthesis of ester bonds. If 5'-mononucleotides are in solution at millimolar concentrations, then oligomers resembling RNA are synthesized and exist in a steady state with their monomers. Furthermore, if the mononucleotides can form complementary base pairs, then some of the products have properties suggesting that secondary structures are present, including duplex species stabilized by hydrogen bonds.

P2-14 Kuhan Chandru

The Unknown Complexes in Prebiotic Chemistry

The question of the origin of life has intrigued experimentalists since the demonstration of the possible abiotic formation of amino acids by Miller in 1953. Since then, many experiments have been shown how other bio-molecules (e.g purine, pyrimidines, fatty acids) can be formed using apparatuses similar to Miller's as well as hydrothermal reactors. Interestingly, a considerable amount of literature has been published regarding the polymerization of amino acids in prebiotic simulations. These studies have shown that when a single amino acid, such as glycine, is used, depending on the experimental conditions, peptides up to hexamers can be detected, suggesting that their uncatalyzed abiotic formation is possible without the involvement of ribosomes. However, these findings has been challenged by several authors, arguing that implausibly high concentrations of reactants are often needed for such syntheses. It is also worth noting, that the products of glycine reactions are relatively easier to predict due to glycine's simple structure than in cases in which multiple amino acids are used. To date, there has been little research into the degree of polymerization when multiple types of amino acids are heated; complication could arise simply due to reaction among the amino acids' side chains.

P2-15 Chris Joseph Butch

High pH Chemistry of Glyoxylate as a Starting Point for a Prebiotic Metabolism

I will present the potentially prebiotic conversion of glyoxylate to tartrate under high pH conditions. Subsequent conversions of tartrate allow production of oxaloacetate, pyruvate, and from pyruvate, most intermediates of the citric acid cycle. I will discuss potential conditions under which these transformations could take place, and identify avenues for future research.

P2-16 Vincent Oostelbos

Genetic takeover: From pre-RNA to the RNA world

Although progress continues to be made in solving problems with de novo synthesis of RNA molecules as an approach to abiogenesis, the difficulties with this synthesis suggest a simpler molecule may have preceded RNA as a genetic code. This simpler molecule must then later have been replaced by RNA in a process known as genetic takeover. Through computer modeling, we aim to analyze the possibility of such a process and to identify which factors may have contributed to its occurrence.

P2-17 Masashi Aono

Improvements in Amoeba-inspired Heuristic Search Dynamics for Exploring the Origins of Life

We propose a nature-inspired model for simulating chemical reactions in a computationally resource-saving manner. The model was developed by extending our previously proposed heuristic search algorithm, called "AmoebaSAT," which was inspired by the spatiotemporal dynamics of a single-celled amoeboid organism that exhibits sophisticated computing capabilities in adapting to its environment efficiently. AmoebaSAT is used for solving an NP-complete combinatorial optimization problem, "the satisfiability problem," and finds a constraint-satisfying solution at a speed that is dramatically faster than one of the conventionally known fastest stochastic local search methods for a class of randomly generated problem instances. In cases where the problem instance gives has more than one solution, AmoebaSAT exhibits dynamic transition behavior among a variety of the solutions. Inheriting these features of AmoebaSAT, we formulate "AmoebaChem," which explores a variety of metastable molecules in which several constraints determined by input atoms are satisfied and generates dynamic transition processes among the metastable molecules. AmoebaChem and its improved forms will be applied to the study of the origins of life, since they will be used to discover a variety of reaction paths for which expected or unexpected organic compounds are may be formed through passing via unknown intermediates and to estimate the likelihood of each of the discovered paths.

P2-18 Kazuaki Amikura

A genetic code without the sulfur containing amino acids

A “simplified genetic code”, with only 19 amino acids assigned to the sense codons, was developed (Akio Kawahara-Kobayashi. et al., (2013), NAR). In this poster, we describe novel simplified codes in which sulfur-containing amino acids are simultaneously excluded from the universal code. In the simplified code, methionine and cysteine codons on ORF are assigned to serine by using three kinds of tRNASer. Additionally, in the simplified code, start codon are assigned to glutamine by using tRNAfMet variants. A simplified genetic code is useful as an engineering tool for the improvement of industrial enzymes and pharmaceuticals, and also provides new insights into the assessment of protein evolution. Simplified codes in which multiple amino acids are simultaneously excluded from the code can be more effective tools than codes excluding only one amino acid.

P2-19 Shigenori Maruyama

A way to establish Astrobiology

One of an ultimate mysteries of Science is the existence of life in the Universe. In regard to this question, three ideas have been provided; (1) The Universe teems with life, (2) No other life other than Earth life, and (3) between 1 and 2. Also, we have two simple questions about life. (1) Is primitive life constantly emerging on present Earth? (2) Once whole life is killed, another new Earth life will emerge on the Earth? The answer to both questions is No.

Astrobiology is the academic field that can provide minimum conditions to bear life in the Universe, and also collateral conditions to make a planet to have civilization. Here we summarize such conditions to have life with civilization. To emerge life on the Earth, there are numerous kinds of conditions which are intricately interrelated. Here, we categorized such complex conditions into three groups. (1) Conditions to make life-sustainable planets derived from planetary formation theory. This category lists 19 conditions. For example, elliptical orbit is unacceptable condition for life. Even if f such planet is covered by liquid water, planet is to experience snowball for half the year, and for other half year water component turn to vapor due to red hot scorching environment like Venus. (2) Conditions to emerge and evolve life on the planet. This category includes 7 significant conditions which control the emergence and evolution of life. One of conditions is lifetime of carbon. Carbon is necessary component for life body, however the amount of carbon for life is decreasing through time. Carbon will be depleted in 1 billion years, indicating termination of life. (3) Conditions to have civilization on the planet. This category has 5 conditions. The most significant condition is brain development. Discontinuous upgrowth of brain differentiate human being from chimpanzee, and human is to establish civilization finally.

Day 3 (Thursday, January 15, 2015) - Signs of Life on Other Planets

P3-01 Jennifer Buz

A Reinvestigation of the ALH84001 magnetites using SQUID Microscopy

ALH84001 is a ~4 Ga Martian meteorite famous for the magnetite-bearing carbonate films it possesses along its fracture surfaces. Great debate has raged concerning the origin of these magnetites, some of which bear a striking similarity to those produced by magnetotactic bacteria. The two leading hypotheses to explain the origin of the carbonate-hosted magnetites are: (1) the magnetite formed during high-temperature shock deformation leading to the decomposition of siderite to magnetite, and (2) mature magnetite crystals were deposited in an aqueous micro-environment. The latter hypothesis is consistent with a biogenic origin for the magnetites. Previously, magnetic studies of the ALH84001 carbonates were not possible due to their small size. However, ultra-high resolution scanning superconducting magnetic microscopes have increased our measurement sensitivity 4 orders of magnitude over conventional superconducting magnetometers. We have used this instrument to measure the magnetic moments associated with 50-μm sized carbonate fragments. We are in the process of demagnetizing individual carbonate blebs for eventual application of the Fuller test of natural remanent magnetization, which will distinguish between the two aforementioned hypotheses. Additionally we have scanned successive slices of a small piece of ALH84001 for use in a three-dimensional view of the magnetic fields within the meteorite. This may enable us visualize the fracture surfaces within the meteorite and view the magnetization associated with them.

P3-02 Abigail Ann Fraeman

Habitable Environments Preserved in Lower Mt. Sharp: Exploring Curiosity's Future Path from Orbit

Data from satellites in Mars orbit show the lower portion of Mt. Sharp exposes minerals and textures that formed in a range of diverse geochemical environments, some of which may be associated with previously habitable conditions (Anderson et al., 2010; Milliken et al., 2010; Fraeman et al., 2013). We combine CRISM, HiRISE, and THEMIS orbital datasets to generate a detailed stratigraphic map of lower Mt. Sharp that provides a context for the Curiosity Mars rover's landed investigation of the area. The lowest unit of Mt. Sharp (the "Murray formation") contains sulfate minerals and hematite, and both are associated with light fractured terrain that lacks clear bedding. This unit has a vertical thickness of several hundred meters, suggesting the processes that formed it were long-lived. In addition to being present in outcrops throughout the Murray formation, hematite is also detectable as large localized outcrops across multiple stratigraphic layers. The spatial distribution of these outcrops suggests the hematite in these areas is a secondary phase that formed in regions of localized iron oxidation at a chemical interface. In terrestrial environments, similar processes are often mediated by chemolithotrophic microorganisms, and the hematite-bearing areas represent prime candidates for previously habitable environments. The Murray formation is topped by another unit containing Al, Fe-smectites, a phyllosilicate mineral. A key question is whether the units and the minerals within them represent sedimentary materials deposited in a paleolake and open to the Mars atmosphere or non-aqueously deposited sediments later altered by groundwaters. Lacustrine deposition followed by diagenesis is a third possibility. Future ground-based textural, chemical, and mineralogical investigations of these areas by Curiosity will help elucidate their formation conditions and habitability potential.

P3-03 Mathieu Gaetan Andre Lapotre

How much water on Hesperian Mars - Insights from canyon morphology

Early in their history, Earth and Mars took very different paths when it comes to water. On Mars, most of the water migrated to the subsurface around the Noachian to Hesperian boundary, only to burst out to the surface episodically in the form of catastrophic floods. Similar catastrophic floods occurred through Earth's history when glacial lake dams failed. On both planets, such floods eroded canyons in basalt that often have steep sidewalls and amphitheater heads, suggesting erosion by waterfall retreat and block toppling. Two paleohydraulic methods are typically used to reconstruct flood discharges. The first is based on the discharge required to move sediment, which requires rare grain-size data and is necessarily a lower bound. The second assumes bedrock canyons are entirely inundated, which likely greatly overestimates the discharge of canyon carving floods. Here we explore a third hypothesis that canyon width is an indicator of flood discharge. To test this hypothesis, we need data on how outburst floods focus water into canyons across a wide range of canyon and flood sizes. To fill this data gap, we performed a series of numerical simulations solving the 2D depth-averaged shallow water equations for turbulent flow. We analysed the effect of five non-dimensional parameters on the shear stress and discharge distributions around head and sidewalls of canyons of different sizes. The Froude number of the flood has the greatest effect on the distribution of shear stresses and discharges around the canyon rim. Simulation results show that canyons of constant width were likely carved by floods within a relatively narrow range of discharges. Example applications on Earth and Mars show that our flood reconstructions yield canyon-carving discharges larger than inferred from incipient motion thresholds, and often dramatically smaller than inferred from assuming complete canyon inundation.

P3-04 Louis Lerman

Prebiotic Chemical Evolution on an Early Mars: Consequences and Artifacts of 'Organic' Weather Cycles in the Noachian

Recalling that the conditions suitable for life's habitability are not necessarily those needed for its origin, this is a first attempt to build a 'universal' theory of life's (potential) origin on a warmer, wetter younger Mars. The universalities of chemical physics provide surprisingly detailed insights into the hydrology and weather cycles of Mars' past; offering further critical insights into whether life could have arisen on Mars through the process of chemical evolution. Requiring only liquid water and simple amphiphiles local 'organic weather cycles' inevitably form when the Rayleigh-Taylor instability in water is metastabilized by simple organic compounds. These lead to a complex set of mutually transforming phase transitions fundamental to supporting chemical evolution through the organizing properties of the air-water interface along with its smaller scale microenvironments - bubbles, aerosols, and droplets. A significant subset of these cycles (weather and the subsequent organic self-organization) is likely even if surface waters were only short-lived lakes and intermittent turbulent flows, for which there is now abundant evidence for the existence of on an earlier Mars. Since the essential chemical physics occurs at the interface of the water's edge it matters little if the water was three miles deep or three inches. Early Martian weather cycles could thus provide functional support for an independent "origin" of Martian life through organic chemical self-organization. One possible consequence is that Martian blueberries nucleated around organic matter, similar to their closest terrestrial analog, concretions. Also on Mars, artifacts of these prebiotic processes could mimic fossilized evidence of "life", providing abiotic origins for ALH8401-like "nanobacteria"; yet simultaneously preserving evidence of past conditions and processes capable of supporting the functional requirements of chemical evolution.

P3-05 Renyu Hu

Carbon Reservoir History of Mars Constrained by Atmospheric Isotope Signatures

The evolution of the atmosphere on Mars is one of the most intriguing problems in the exploration of the Solar System, and the climate of Mars may have evolved from a warmer, wetter early state to the cold, dry current state. Because CO_2 is the major constituent of Mars's atmosphere, its isotopic signatures offer a unique window to trace the evolution of climate on Mars. Here we derive new quantitative constraints on the amount of carbonate deposition and the atmospheric pressure of Mars through time, extending into the Noachian, ~3.8 Gyr before present. This determination is based on recent Mars Science Laboratory (MSL) isotopic measurements of Mars's atmosphere, recent orbiter, lander, and rover measurements of Mars's surface, and a newly identified mechanism (photodissociation of CO) that efficiently enriches the heavy carbon isotope. In particular, we find that escape via CO photodissociation on Mars has a fractionation factor of 0.6 and hence, photochemical escape processes can effectively enrich 13C in the Mars's atmosphere during the Amazonian. As a result, modest carbonate deposition must have occurred early in Mars's history to compensate the enrichment effects of photochemical processes and also sputtering, even when volcanic outgassing up to 200 mbar occurred during the Hesperian. For a photochemical escape flux that scales as the square of the solar EUV flux or more, at least 0.1 bar of CO_2 must have been deposited as carbonates in the Noachian and Hesperian. More carbonate deposition would be required if carbonate deposition only occurred in the Noachian or with low fractionation factors.

P3-06 Sebastian Oscar Danielache

Chemistry with KROME II: A dynamical photochemical core coupled with disequilibrium and sulfur isotopes

The study of chemical networks of Earth's geological past such as the Archean and Exoplanetary atmospheres requires the resolutions larges number of chemical reactions. This necessity is based on the lack of observational parameters abundant in today's planet Earth or neighbor planets in the solar system. The aim of this work is to construct a planetary atmosphere chemical network solver that relies on a minimal number of observational parameters. We present here the latest development in our effort to develop such model. Our previous report presented the efficiency of the chemical solver for a large number of chemical species and reaction networks. In this report we present a photochemical dynamic core capable of solving ultraviolet opacities and photo-dissociation reaction rates at each step of the calculation. Additionally the model has been equipped with a set of equations to calculate disequilibrium effects on the chemical network. The stability and robustness of the code has been tested for a large network with more than 500 reactions interlinking more than 40 chemical species. The results obtained so far have been contrasted with the most common chemical codes available in the literature for benchmark.

P3-07 Alexis Gilbert

Tracing the origin of natural gas hydrocarbons using position-specific isotope analysis

Natural gas hydrocarbons are ubiquitous components occurring in a wide range of environments. Distinguishing the origin of natural gas has wide implications for the origins of life, such as understanding the geochemistry associated with hydrothermal systems or tracing biogenic and non-biogenic organic matter for extraterrestrial exploration. Despite tremendous efforts using chemical and isotopic analyses (^{13}C, ^{2}H), a clear distinction is often made difficult due to overlap of signatures for different origins. Clearly therefore, new proxies must be explored in order to refine the origin information on natural gas components (methane, ethane, propane, butanes, pentanes). Position-specific isotopic approaches, namely isotopic distribution within a single molecule, is expected to provide unique information on the origin of organic compounds. Although, their potential remains clearly underexploited particularly due to the limited technological developments. Here we evaluate a system consisting of on-line pyrolysis coupled with GC-C-IRMS for the determination of the position-specific ^{13}C isotopic composition of short-chain hydrocarbons (propane, *n*-butane, *i*-butane). This system enables the breakdown of hydrocarbons and subsequent analysis of the fragments formed from which the original intramolecular isotopic composition can be calculated. Preliminary results show different position-specific isotope composition depending on the source of the hydrocarbons. Such an approach will be useful in the future in order to (i) study the mechanisms responsible for abiotic formation of natural gas on Earth, (ii) clarify the origin of hydrocarbons from the geological record and (iii) identify the source of natural gas components detected on other planets.

P3-08 Yuhito Shibaike

Melting of Hadean Continents by Late Heavy Bombardment and Origin of Life

Hadean is considered to be the eon of origin of life and the existence of Hadean continents is likely to be necessary for birth of life. Although there are no Hadean rocks on the Earth, some Hadean zircons those are considered to be evidences of the existence of continental crusts were found. Therefore, it is considered that some Hadean continents existed and some process deleted the continents. There is a hypothesis for the delete process; destruction and/or melting of Hadean crusts by Late Heavy Bombardment (LHB), which is a concentration of impacts in last phase of Hadean. In this study, we verified this hypothesis quantitatively and systematically, and showed there are few possibilities for LHB to delete the whole Hadean continental crusts. We approximated the SFD of impacts with a power-law scaling, and gave a power index α as a parameter. Then, we derived semi-analytical expressions for the effects of LHB to the crust. We calculated the total volume and area of destruction and melting by LHB from two independent traces on the Moon; the maximum mass hit the Moon during LHB and the density curve of lunar craters larger than 20 km. However, the α range that LHB could destruct/melt the whole Hadean continents is very limited. Also, where α=1.61, the SFD fulfill both the two traces, LHB could only cover about 2% of the surface area of the Earth by melts. If we consider the flood melts from under the crust, melting area reached half of the Earth's surface. Moreover, including the effects of pre-LHB impacts, more surface area of the Hadean Earth was likely to be covered by these melts. The flood melts must have been composed of mixture of crusts and mantle like the magma ocean and formed a lot of "magma pools," local version of the magma ocean. In such magma pools, KREEP-like components may have been formed on surface of the Earth by differentiation of the melts, and they were likely to be the source of potassium and phosphorus, essential elements for birth of life.

P3-09 Juan Pedro Ferrio

Drinking rocks: plants can use crystallization water from gypsum mineral

Some minerals, like gypsum, hold water in their crystalline structure. The activation energy of the dehydration reaction of gypsum is relatively low and the conversion of gypsum to bassanite ($CaSO_4 \cdot ½H_2O$) or anhydrite ($CaSO_4$) may take place at ambient conditions. Although still unexplored, the use of such crystallization water by organisms would point to a completely new water source for life, critical under dry conditions. Here we present the results of a recent study(1), in which we analyzed the hydrogen (δ^2H) and oxygen ($\delta^{18}O$) isotope composition of the xylem water of shallow-rooted plants growing on gypsum, and compared it to the isotopic composition of the free and crystallization water of the gypsum soils where they grow. According to our results, the isotopic composition of the xylem sap of plants was closer to gypsum crystallization water than to free soil water, particularly during the dry summer. Bayesian stable isotope mixing models indicated that gypsum crystallization water accounted for up to 90% of the water used by these species during summer. Plants could also uptake gypsum crystallization water during spring, when it accounted for up to 30% of the xylem sap of plants. Although the underlying mechanisms require further research, this is the first experimental evidence in support of the role of gypsum crystallization water as a water source for life. Our results change the current paradigm on water use by plants, where water held in the crystalline structure of mineral rocks is not regarded as a potential source. Given the existence of gypsum on the surface of Mars and its widespread occurrence on arid regions worldwide, these findings have important implications for exobiology, the study of life under extreme conditions and arid land reclamation.

1. Palacio, S., Azorín, J., Montserrat-Martí, G. and Ferrio, J. P. 2014. The crystallization water of gypsum rocks is a relevant water source for plants. Nature Communications 5 (doi:10.1038/ncomms5660)

P3-10 Jun Kimura

Polymerization of building blocks of life on Europa and other icy moons

The outer solar system may provide a potential habitat for extra-terrestrial life. Remote sensing data from the Galileo spacecraft support that the Jovian icy moons Europa, Ganymede, and possibly Callisto may harbor liquid water oceans underneath the icy crusts. Although compositional information required for the discussion of habitability is highly limited because of significantly restricted observation data, organic molecules are ubiquitously present in the universe. Recently, in-situ spacecraft measurements and experiments suggest that amino acids can be formed abiotically on interstellar ice and comets. These amino acids could be continuously delivered by meteorite or comet impacts to an icy moon. Here we show that polymerization of organic monomers, in particular amino acids and nu-cleotides, could proceed spontaneously in the cold environment of icy moons, in particular the Jovian icy moon Europa as a typical example, based on thermodynamic calculations, though kinetics of formation are not addressed. Observed surface temperature on the Jovian icy moon Europa is 120 and 80 K in the equatorial region and polar region, respectively. In such low temperatures, Gibbs energies of polymerization become negative values, and estimated thermal structure of the icy crust expects that the shallow region (i.e., at a depth of only a few kilometers) of the crust is favorable for polymerization. Investigation of the possibility of organic monomer's polymerization on icy moons could provide good constraints on the origin and early evolution of extraterrestrial life.

P3-11 Steve Vance

Thermodynamic Equations of State for Ammonia and Sodium Chloride Solutions Applied to Deep Icy World and Exoplanet Oceans.

Fluid-rock interactions in such bodies have been regarded as limited by the negative buoyancy of high pressure ice phases V, VI, VII, and VIII. An analogous assumption exists for larger icy worlds in the solar system, including Ganymede and Titan, where ocean depths approach 800 km and GPa pressures (>10katm). We have previously demonstrated temperature gradients on the order of 20 K that result from fluid compressibil-ity in a deep adiabatic ocean based on our experimental work. Accounting for increases in density for highly saline oceans leads to the possibility of oceans perched under and between high pressure ices. Ammonia has the opposite effect, instead decreasing ocean density, as reported by others and confirmed by our laboratory measurements in the ammonia water system. We report on the completed equation of state for aqueous ammonia derived from our prior measurements and optimized global b-spline fitting methods. Using sound velocity measurements obtained in our laboratory, we con-structed a self-consistent thermodynamic framework for the binary ammonia-water system. Densities show much less temperature dependence, but high pressure derivatives comparable to previously published ammonia-water properties derived for application to Titan. New equations of state allow us to assess the influence of ocean salinity on the thickness of layers of ice I-II-III-V-VI in the interiors of these objects, and to infer associated ocean dynamics. Ocean compositions with salt or am-monia have less high-pressure ice. In some model oceans, high-pressure ice phases become buoyant relative to sur-rounding fluids, implying frazil-like upward snows, interlayered liquids and ices, and fluids in direct contact with rock. We discuss the roles of dissolved constituents in watery super Earth's in the context of models for their internal mass distribution.

P3-12 Masashi Omiya

Search for extrasolar Earth-mass planets around low-mass stars using InfraRed Doppler

Planetary systems around low-mass stars (0.1-0.3Msun) are attractive targets to detect such Earth-mass planets in the habitable zone because of relatively large Doppler signals caused by the planets and their close-in habitable zone. For the advantages, we have a plan to conduct a planet search program of low-mass stars by the Doppler method using a new InfraRed Doppler (IRD) instrument. IRD to be mounted on the Subaru telescope in 2015 is composed of a very stable near-infrared high dispersion echelle spectrograph and a laser-frequency comb as a wavelength calibrator of the radial velocity measurements. The main goals of the program are to detect Earth-mass planets in the habitable zone and to understand statistical properties, formation and habitability of extrasolar Earth-mass planets around low-mass stars. In my presentation, I introduce current status of our project, as well as expectations for the detectable planets in the IRD/Subaru planet search program.