use. Survival of plants and coexistence of different species is discussed in relation to their drought tolerance and water use efficiency, under conditions of temporal and spatial environmental variability

B52B MCC: Level 2 Friday 1330h

Astrobiology as a Unifying Theme for Solar System Exploration II Posters

(joint with P)

Presiding: **D Morrison,** NASA Astrobiology Institute**; B Runnegar,** University of California, Los Angeles

B52B-1034 1330h POSTER

Bugbuster: Survivability of Living Bacteria Upon Shock Compression

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Survivability of bacteria during impact events has implications both for the transport of life between planets and development of organisms on Hadean Earth and other planets during the period of heavy bombardment which ended 3.5 Gyr before the present [1]. We envision that life existed within internal rock surfaces immersed in the early ocean. We performed shock recovery experiments on live *E. coli* bacteria to determine survival rate vs. shock pressure. Samples of 2x10^7 cells were suspended in $\sim 10^{-5}$ l of a buffer solution (TE: a 10:1 solution of Tris and EDTA), sealed into stainless steel chambers that are impacted by 1.5 mm thick flyer plates at 670-760 m s^{-1} using a 20 mm gun. Recovered liquid was mixed with a nutrient broth (LB: growth medium containing tryptone, yeast extract and NaCl) and spread on a Petrie dish containing agar (a polysaccharide growth medium extracted from marine algae *Rhodophyceae*). Recovered samples were cultured for ∼16 hours at 37° C. In addition, sample bacteria studied under an optical microscope with DAPI fluorescent stain to verify presence of bacteria in shock recovered samples. Initial and reverberated shock pressures in H_2O varied from 0.2 to 2.0 and 2.4 to 14.9 GPa respectively. We modeled the bacteria cell walls with stilbene, ρ_0=1.16 g cm^{-3}, U_S=2.866+1.588u_P and the cell interiors as water. Upon initial loading the net strain imposed on *E. coli* that just caused non-survival for 10^{-6} s duration stress was 2.8. If this strain is characteristic of that tolerable by *E. coli*, we predict that shock stresses of 25 MPa, 25 kPa and 25 Pa are sustainable upon shock loading by 0.1 ms, 0.1 s and 100 s shock duration pulses. Such shock durations are induced by 2.5 m, 2.5 km and 2,500 km diameter silicate impactors. **References:** [1] Maher K.A. & Stevenson D.J., *Nature*, **331**, pp.612-614, 1988

B52B-1035 1330h POSTER

Definitive Mineralogical Analysis of Martian Rocks and Soil Using the CheMin XRD/XRF Instrument

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The search for evidence of life, prebiotic chemistry or volatiles on Mars will require the identification of rock types that could have preserved these. Anything older than a few million years will either be a rock, or will only be interpretable in the context of the rocks that contain it. The key role that definitive mineralogy plays is a consequence of the fact that minerals are thermodynamic phases, having known and specific ranges of temperature, pressure and composition within which they are stable. More than simple compositional analysis, definitive mineralogical analysis can provide information about conditions of formation, past climate, water activity, the fugacity (activity) of biologically significant gases and the like. The CheMin XRD/XRF instrument is capable of definitive mineralogical analysis. A wide variety of minerals and rocks has been analyzed utilizing 40 KV accelerating voltage and 0.25 amps beam current (10 watts). Interpretable patterns of single minerals can be obtained in a few minutes and quantifiable patterns of complex rocks can be obtained in a few hours. A CheMin flight prototype is being designed for the Mars '09 MSL opportunity. It will utilize a CCD detector based on the MER '03 camera and a miniaturized, low-power carbon nanotube field emission X-ray tube. The CheMin flight prototype will weigh less than a kilogram and will operate with as little as five watts of power (although increased power will result in shorter data acquisition times).

B52B-1036 1330h POSTER

Development and Test of a Probe to Remotely Sense Microbial Life

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Fluorescence spectroscopy is a powerful and highly sensitive tool useful for remotely searching for subsurface microbial life. Ubiquitous biomolecules in microorganisms (e.g. tryptophan and NADH) have unique autofluorescence spectra that allow them to be optically detected at low levels even in the presence of a fluorescence background from minerals. Based on this technique, we have developed and tested a first-generation Biospectral Logger (BSL); an instrument suitable for logging boreholes and aquatic environments which uses a 370 nm excitation source and a bank of seven notch-filtered phototubes to record the spectrum of microbial NADH fluorescence. The first generation BSL was constructed and tested in Lake Tahoe, where it recorded chlorophyll fluorescence that peaked at a depth of about 57 m and then decreased with depth. NADH fluorescence was found to peak and fall off with chlorophyll for shallow depths, but then began increasing again at deeper depths, which agrees with the results of independently performed cell counts. In order to optimize the discrimination between microbial life and its environment, we used a laboratory fluorimeter to map out the emission spectra of a diverse collection of microbes and minerals as a function of excitation wavelength, which we varied between 224 nm and 460 nm. Based on these data, we have planned future developments of the BSL technology that make it more selective and able to be used in more extreme environments such as deep mine boreholes, permafrost, deep-ocean settings, and ultimately Martian permafrost, where its greatly-increased sensitivity will be sufficient to detect microbial concentrations down to 1 cell/cm3 in media with relatively low background

B52B-1037 1330h POSTER

The Search for Organics (δ^{13}C and δ^{15}N) Throughout a Sub Basement Fossil Soil (Ocean Drilling Program, Leg 197): Implications for Earth/Mars deep subsurface

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Detecting organics buried deep beneath the surface of a planet is a fundamental step to constrain the presence and evolution of life on a planet. This is especially true for Mars with barren-life surface owing to extreme settings (UV flux, P atm and T). However, organics and/or viable microbes could still preserved at some deeper locations on Mars [e.g.,1]. This work presents the first nitrogen isotope (δ^{15}N) data for deeply buried Early Tertiary fossil soil Unit (Core 197-1206A-40R; 307.5-309.9 mbsf). They were RCB-cored from the volcanic basement at Site 1206 (Koko Seamount, 34°56' N; 172°9' E) during the ODP Leg 197 (Emperor Seamounts, north Pacific). These Fe-rich, palagonite-bearing soils were formed on the top of subsiding atolls and subsequently buried by lava flows in a near shore environment [2]. Burial rates higher than average subsidence rates ensured the isolation of these fossil soils in a present-day sub-basement setting and their decoupling from the ocean and the atmosphere for likely >54 Ma. Leg 197 soils contain very low, but reliable amounts of total organic carbon (TOC=0.01-0.12 %wt, ± 0.02%, N=36; [2-3]). The single fossil soil unit has stable isotope values more negative (i.e., δ^{13}C-org. = $-25.3^o/_{oo}$ to $-26.2^o/_{oo}$;[4]) and δ^{15}N-tot = $-9.5^o/_{oo}$ to $+2.5^o/_{oo}$ than those of exposed Hawaiian counterparts (i.e., δ^{15}N-tot = $>=0^o/_{oo}$ to $+8.5^o/_{oo}$). This isotopically lighter Ntot could be interpreted as bacterial fractionation throughout the N-cycle either occurred in the past (Early Eocene/Late Paleocene) and changing organic source (C-3, C-4-plants, bacterial) and N-cycle associated processes. However the existing data-set [2-4] need to be compared with microbiological data to establish the potential for these soils to serve as a suitable analog for a possible Mars near-surface/deep biosphere.

[1]Mancinelli, R.L, 2000. Planet. Space Sci., 48:1035-1043; [2] Shipboard Scientific Party, 2002, Proc. ODP, Init. Repts. 197: College Station, TX; [3] Bonaccorsi, R., 2002. EOS Trans AGU, 83(47), Fall Meet. Suppl. Abstract;[4]Meyers, P.A., 1997. Org. Geochem., 27, 5/6:213-259.

B52B-1038 1330h POSTER

The Habitability of Mars: Lessons From Ophiolites on Earth

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Ophiolite sequences, sections of lower oceanic crust and upper mantle that have been thrust onto continental craton, are located in northern and central California. These rock suites provide easily accessible outcrops that likely parallel the rock types on Mars. We have begun investigating and characterizing these sites in order to understand better the processes that may be responsible for the water chemistry, mineralogy and biology on Mars. The ophiolites found in northern and central California include the Trinity, Josephine, Coast Range and Point Sal, and all are approximately 160 million years old. These ophiolite bodies are actively serpentinizing. Fluids from serpentinizing springs are generally alkaline, with high pH and H2 contents, indicating that the mafic rock compositions control the fluid chemistry through water-rock reactions during relatively low-grade hydrothermal processes. The general reaction describing the serpentinization of olivine is given by: olivine + H2O = serpentine + brucite + magnetite + H2. We have analyzed the petrography and mineralogical composition of a number of rock samples collected from the Coast Range Ophiolite near Clear Lake, CA by electron microprobe. The remnant primary mineralogy is fairly uniform in composition, with an olivine composition of Fo90, and with pyroxene compositions of En90 for orthopyroxene and En49Wo48Fs03 for the clinopyroxene. There are several generations of alteration products, comprised mostly of serpentines that are magnesium rich, with magnetite, brucite and carbonates observed as accessory minerals. The oxidation of iron in the ferrous component of olivine (and pyroxene) results in the generation of H2, as indicated by the presence of magnetite. The formation of carbonates can be taken to indicate the presence of CO2 in the altering fluids. The H2 generated through water-rock reactions in these systems may provide an energy source for chemolithoautotrophic ecosystems, while the CO2 serves as a carbon source. The identification of several species of Archaea from these rocks, including an alkalophile, indicates that these geochemical environments do serve as habitats. We suggest that serpentinizing springs in mafic to ultramafic terranes may be the most likely areas on Mars to be habitable.

B52B-1039 1330h POSTER

Magnetic Fe,Si,Al-rich Spherules From the P-T Boundary Layer at Graphite Peak, Antarctica

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Recently we have reported on the discovery of meteoritic fragments of the CM chondrite affinity in two samples (#2060 and #A315, see Basu et al, submitted to Science and Basu et al., this meeting) from the P-T boundary at Graphite Peak, Antarctica. Here we report on meteorite fragments from a third sample (#A314) from the P-T boundary in this location associated with numerous small (0.018 - 0.053 mm across) vesicular spherules enriched in SiO2 (32 - 60 wt %), Al2O3 (7 - 22 %), and FeO (12 - 62 %). Most spherules typically consist of a silicate glass which often contains either blocky crystals of a SiO2 polymorph in the SiO2-enriched spherules or skeletal magnetite crystals in the FeO-enriched spherules. Few spherules consist mainly of magnetite with rare interstitial patches of a silicate glass. Although the chemical composition of the glass varies from spherule to spherule, the high concentrations of TiO2 (0.48 - 2.48 %), Al2O3, and K2O (0.58 - 3.10 %) along with the lack of Cr2O3, MnO, and NiO unequivocally point to the terrestrial crustal origin of the spherules. Moreover, high FeO and low CaO (0.75 - 4.93 %) concentrations suggest either a sedimentary or metamorphic rather than an igneous precursor. The wide compositional variations along with the quenched textures of the spherules are consistent with their impact origin. Thus, the association of the spherules with meteorite fragments at the P-T boundary lends further support to the catastrophic collision of Earth with a large celestial body in the end-Permian which might have been responsible for the global extinction event at the P-T boundary.

B52B-1040 1330h POSTER

Chondritic Meteoritic Fragments Associated With the Permian-Triassic (P-T) Boundary in Antarctica: Evidence for an end-Permian Bolide Impact.

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We report the discovery of meteoritic fragments, as large as 400μm in size, in an end-Permian sedimentary bed in Graphite Peak, Central Transantarctic Mountains, Antarctica. Here, the P-T boundary is well constrained isotopically and paleontologically, and its lithology is well documented. The boundary at this site is also characterized by fullerenes containing extraterrestrial ^{3}He and shocked quartz grains. We found meteoritic fragments in two samples of a claystone-breccia bed (separated stratigraphically by 23cm) that rests directly above the coal horizon with the last occurrence of *Glossopteris*. The meteoritic fragments display poikilitic or granular texture with euhedral-subhedral forsterite crystals enclosed in larger clinoenstatite grains showing polysynthetic twinning. Some silicate grains contain tiny inclusions of Fe, Ni-metal grains with chondritic Ni/Fe and Co/Ni ratios. Overall, Ni/Fe, Co/Ni and P/Fe ratios in the metal grains, Fe/Mg and Mn/Fe ratios in olivines and pyroxenes, and the chemistry of Fe, Ni, P, S-bearing oxides within the meteoritic fragments are typical of CM chondritic meteorites. The meteoritic grains found in magnetic separates of the sediments are accompanied by abundant metal nuggets, which are also found in an end-Permian bed from Meishan, south China. The common occurrence of these Fe-Ni-Si metal grains at Graphite Peak and at the Meishan P-T section provides further evidence that we sampled the P-T boundary at Graphite Peak. The association of metal grains with discrete meteoritic fragments at the Graphite Peak P-T boundary along with previous reports of such metal grains from other P-T localities leads us to support a catastrophic collision of a celestial body with the Earth at the end-Permian. We believe that this is what caused the global extinction event at the P-T boundary. Thus it appears that the two largest mass extinctions in Earth history at the K-T and P-T boundaries were both caused by catastrophic collisions with chondritic meteoroids.

B52B-1041 1330h POSTER

Miniature Electrospray Ionization/Ion Mobility Spectrometer System for Detection of Organic Molecules on Mars

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The potential of an Electrospray Ionization/Ion Mobility Spectrometer (ESI/IMS) either as a stand-alone ana-lytical instrument or as part of a suite of instruments on the proposed 2009 Mars Science Lander (MSL) for analyz-ing material extracted from rock and soil samples will be demonstrated. We constructed a miniature, self-contained ESI/IMS instrument which is presently undergoing feasibility testing as part of the Mars Instrument Development Program (MIDP). This instrument, which contains minimal moving parts and is very economical to construct, would be ideal for a small rover searching for specific organic molecules on Mars. The ESI/IMS instrument will be able to identify volatile compounds as well as resident organic molecules on the parts-per-billion (ppb) level both on and near the surface. Also, it will be able to obtain an inventory of salts, on the surface of Mars which will result in a better understanding of ongoing surface chemistry. ESI is a powerful ionization method. It can extract fragile organic species from solution intact, ionize them and transfer them into the gas phase where they can undergo analysis. A great advantage of ESI is its ability to provide soft ionization resulting in the ionization of non-volatile and fragile organic molecules with little fragmentation. IMS is a high-pressure time-of-flight (TOF) method based on elastic collisions of an ion with a buffer gas. It is advanta-geous over the other detection methods because it can operate at the same pressure as the ESI resulting in no differ-ential pumping when the ions go from ionizer to analyzer. Each species has an average drift velocity, which is proportional to the applied electric field and the ion mobility (K_m). IMS has been demonstrated to be very sensitive in detecting organic compounds, and is currently the instrument of choice for field detection of explosives and chemi-cal/biological warfare agents.

B52B-1042 1330h POSTER

Exploring the Limits to Photosynthetic Life in the Hyperarid Atacama (Chile) and Taklimakan (China) Deserts

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Photosynthetic microbes inhabiting the cracks or fissures (chasmoendoliths) and undersides (hypoliths) of translucent stones function as the sole primary producers in the world's driest deserts. This poster reports on our studies of the distribution and survival of these microorganisms in the hyperarid core of the Atacama Desert–an extreme environment previously considered too dry to support photosynthetic life–and the Taklimakan Desert in China–one of the oldest and driest deserts on the Earth. In both deserts, we measured colonization rates and microclimate variables across natural precipitation gradients in order to investigate the role of moisture in the ecology and survival of hypolithic and chasmoendolithic microorganisms. Our results show 1000-fold variations in colonization rates–from 12% in the wettest portions of the Taklimakan Desert to <1% in the arid core of the Atacama–that correspond at the macro-scale to decreased mean annual precipitation (MAP) of ~45mm to ~ 0mm. In the Atacama, soil Δ^{14}C signatures suggest slow but active organic carbon cycling by hypolithic communities. In the hyperarid core of the Atacama, the Δ^{14}C signature of organic carbon in hypolith-colonized soils beneath translucent stones was -276 $^o/_{oo}$, corresponding to a steady state turnover time of >3000 y. At slightly wetter sites in the Atacama, Δ^{14}C of hypolith soils was progressively more enriched in proportion to increased MAP, with corresponding turnover times of >600 y (Δ^{14}C = -73 $^o/_{oo}$ at sites with ~5-10 mm MAP and ~1 y Δ^{14}C = +12 $^o/_{oo}$) as annual rainfall increased to ~25 mm. At all sites, Δ^{14}C signatures of non-hypolith soils corresponded to turnover times that were longer by an order of magnitude, indicating significantly slower OC cycling by non-hypoliths. In the hyperarid core of the Atacama Desert, the prolonged lack of rainfall (decadal scales of a few millimeters) is responsible for possibly the lowest hypolithic and chasmoendolithic colonization rates observed in deserts on the Earth. Microclimate data for rock and soil surface moisture from rainfall, dew and frost suggest the particular form of moisture and its frequency may also explain observed differences in hypolithic versus chasmoendolithic colonization modes. These results hold theoretical and practical considerations for both terrestrial ecology and as analogs for possible life on Mars.

B52B-1043 1330h POSTER

Subduction of the Carbonated Archean Oceanic-Crust and its Implication to Evolution of Earth's Early Atmosphere

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Geological studies in the Archean greenstone belt have shown that plate tectonics had already started at 3.8Ga, and the ocean floor hydrothermal alteration had formed much carbonate in oceanic crust before subduction [Ohta et al. 1996; Komiya et al. 1999; Nakamura 1999; Hayashi et al. 2000; Kitajima 2003; Shibuya 2003MS]. These observations suggest that the significant amount of carbon had carried into the mantle via the Archean subduction zone. In the present study, we investigated a mode of carbonation of oceanic metabasite in 3.5 Ga North Pole area (East Pilbara greenstone belt, W. Austraria) and estimated the amount of carbon dioxide fixed in the metabasite. Then, subduction flux of carbon dioxide carried into the deep mantle was estimated using phase diagrams for carbonated metabasite and peridotite with the geologically estimated thermal-structure model of the Archean subduction zone. In the North Pole area, carbonate-bearing mineral assemblage is restricted within upper 1000 m from the bottom of bedded chert indicating ancient ocean floor. The highly-carbonated sample consists of carbonate minerals of ca. 60-80 vol%, and mean content of the carbonate mineral in the carbonated zone is roughly 30 vol%. Under the Archean subduction-zone geotherm, the oceanic crust released CO_2 bearing fluid to the wedge mantle, and carbonate minerals such as magnesite were fixed in the peridotite wedge-mantle. The peridotite could contain about 2.6 wt% of CO_2 as carbonate, and the carbonates were stable in the dragged down-going peridotite during subduction. The subduction flux of CO_2 is estimated to be ca. 4.3E11 kg/y, if the production rate of MORB crust in the Archean was as same as in Meso-Cenozoic time. The balance of carbon flux shows that subduction of the carbonated crust reduced surface CO_2 by 3.4E11 kg/y. If this process continued for 1 billion year during the Archean, 3.4E20 kg of CO_2 was removed from the surface into the solid Earth. Using this value, we can constrain the primary CO_2 content in the atmosphere of the earliest Archean or the end of Hadean. The Hadean Earth may have not been covered by an ocean, due to the high XCO_2 in primary atmosphere. Removal of CO_2 from the atmosphere by the subduction of carbonated oceanic-crust may have worked much effectively in smaller planet, such as Mars. This process is possibly a critical factor to determine the fate of terrestrial planet after formation of the ocean.