European Astrobiology Network Association

EANA14

Signatures of Life: From Gases to Fossils

The 14th European Workshop on Astrobiology
October 13th-16th 2014
Edinburgh, UK

-Scientific Programme and Abstracts-

UK Centre for Astrobiology

EANA

UK SPACE AGENCY

#EANA14

Frances Westall

President of EANA

European Astrobiology
Network Association

Dear participants of EANA,

This year we meet in the wonderful city of Edinburgh – where I started my career as a geologist after initially hesitating about becoming an archaeologist. Let's just say, I extended the timescale of my interest in history. That was for geology. And then Astrobiology arrived and so the interest in history became even more extended, as it tends to do in this domain. You start with a specific interest, in my case the earliest traces of life on Earth, and before you know it, you are involved in missions to Mars and the search for life on the red planet, definitions of what is life and how it originated on Earth or elsewhere, how and where the ingredients of life formed, how the planets and satellites in our solar system formed…….how the universe formed ? We have the chance with Astrobiology to be able to do what we love, to consider the most profound questions about life and its surroundings. Our small area of research suddenly takes on a whole new dimension when seen in the context of life …in the WHOLE Universe !

This year is particularly interesting for we astrobiologists. MAVEN has been sucessfully inserted into orbit around Mars to study upper atmospheric processes and to learn more about the present and past climate of the planet, while ,since August, Rosetta is in orbit around the Comet 67P/Churyumov–Gerasimenko (which has a very enigmatic « hour-glass » shape) and Philae will land at site « J » later in the year. Study of this comet will provide us with important information on the nature of the primordial materials that formed early in the Solar System's history and materials which most likely contributed to the volatile inventory of the early Earth. On the exoplanet front, for the first time water vapour has been discovered in the atmosphere of an extrasolar planet – albeit a sterile, gas ball the size of Neptune and named HAT-P-11b, about four times the diameter of Earth and so close to its star that it has a temperature of 600°C. A bit too hot for life but progress is being made in the search for atmospheric signatures of life on exoplanets.

This leads me to this year's EANA meeting, which has biosignatures as its main theme. We will hear about many more exciting discoveries through the broad-ranging programme that promises to be very interesting. And, as each year, the students' contest promises us high level science in a stimulating environment.

We are grateful to Charles Cockell and his team for hosting us and organising the conference. EANA is THE meeting place for European astrobiologists, providing opportunities for interaction and exchange at all levels. I wish you all a happy and fruitfull conference.

Frances Westall

14th European Workshop on Astrobiology

Edinburgh, UK
October 13-16, 2014

Monday October 13th

8:30-9:30	**Registration**
Welcome	
9:30-9:35	Beginning and welcome to venue: Charles Cockell
9:35-9:45	Welcome by the Principal of the University of Edinburgh; Sir Timothy O'Shea
9:45-10:00	President of EANA: Frances Westall
10:00-10:10	Chair of Organising Committee: Charles Cockell
10:10-10:30	The Sounds of Scotland
10:30-11:00	**COFFEE BREAK**

Signatures of Life in Earth's Extremes
Chair: Petra Rettberg
Co-Chair: John Brucato

11:00-11:20	**Barbara Cavalazzi** *Extreme among extremes: Salt and sulphur springs of the Dallol (Danakil depression, Ethiopia) and their astrobiological role*
11:20-11:40	**Ana Miller** *Biosignatures valuable for astrobiology: the case of reticulated filaments*
11:40-12:00	**Sam Payler** *Biogeochemical Cycling and Biogeography in Deep Subsurface Evaporite Deposit Brines*
12:00-12:20	**Sam Kounaves** *Unambiguous Detection of Microbial Growth with Minimal Assumptions*
12:20-12:40	**Kai Finster** *Microbial production of ice crystals in clouds as a novel biosignature*
12:40-14:00	**LUNCH**
14:00-14:20	**Jesse Harrison** *Boundaries for prokaryotic growth in multiple-stress habitats*
14:20-14:40	**Casey Bryce** *Impact shocked rocks as protective habitats on an anoxic early Earth*

Minerals and Signatures of Life
Chair: Martin Lee
Co-Chair: Jean-Pierre de Vera

14:40-15:10	**Dirk Schulze-Makuch** *Microhabitats for microbial life in a liquid natural asphalt lake and their relevance as an astrobiological analog to Titan*
15:10-15:30	**Anja Bauermeister** *Electric Cable Bacteria and Mineralogical Signatures of Life*
15:30-16:00	**COFFEE BREAK**
16:00-16:20	**Joachim Meessen** *UVC-induced photodamage and its attenuation by co-occurring stressors in the photobionts of the astrobiologically relevant lichens* Buellia frigida *and* Circinaria gyrosa
16:20-16:40	**Petra Schwendner** *Anaerobic microorganisms in analogue environments: MASE – an overview*
16:40-17:00	**John Brucato** *Infrared spectral investigations of UV irradiated nucleobases adsorbed on mineral surfaces*
17:00-17:20	**Marie Bassez** *Ferromagnesian rocks in association with carbonates as a signature of life*
17:20-17:40	**Andreas Elsaesser** *Recovery of Amino Acids from Mineral Surfaces – Implications for Life Detection Strategies*
17:40-20:00	**Poster Session and whisky/Scottish gin tasting**

Tuesday October 14th

Minerals and Signatures of Life
Chair: Martin Lee
Co-Chair: Jean-Pierre de Vera

9:00-9:30	**John Parnell** *Demonstrating deep biosphere activity in the geological record of lake sediments*

Plasma and Radiation Hazards to Life
Chair: Gerda Horneck
Co-Chair: Lena Noack

9:30-10:00	**Ralf Moeller** *"The devil is in the detail" - understanding bacterial spore resistance towards plasma sterilization*
10:00-10:30	**Lewis Dartnell** *Life on Venus: radiation hazards to an aerial biosphere*
10:30-11:00	**COFFEE BREAK**
11:00-11:20	**Joop Houtkooper** *Expected Biosignatures from Increases in Entropy and Disequilibrium*

Students' contest: "Space Factor"
Chair: Ralf Moeller

11:20-11:25	**Ralf Moeller** *Introduction*
11:25-11:40	**Michaela Musilova** *Isolation of radiation resistant bacteria from the Antarctic dry valleys by pre-selection and the correlation between radiation and desiccation resistance*
11:40-11:55	**Tareq L Omairi** *Studies on astrobiology with particular reference to cometary panspermia*
11:55-12:10	**Dagmar Koschnitzki** Ignicoccus hospitalis *shows high radiation tolerance although never exposed to it in its natural habitat*
12:10-12:25	**Bo Byloos** *Potential of* Cupriavidus metallidurans *CH34 for biomining from lunar-like basalt by determining the molecular mechanisms behind microbe-mineral interactions*
12:25-14:00	**LUNCH** (International Journal of Astrobiology Board Meeting; *John McIntyre Boardroom 1*)
14:00-14:15	**Ralf Moeller** *Introduction*
14:15-14:30	**Katja Nagler** *Analysis of* Bacillus subtilis *spore germination in high-salinity environments*
14:30-14:45	**Claudia Pacelli** *BIOMEX (Biology and Mars Experiment): Preliminary results on Antarctic black cryptoendolithic fungi in ground based experiments*
14:45-15:00	**Alexandra Perras** *Grappling hooks: The life style and ultrastructure of the SM1 Euryarchaeon which thrives in a Mars analogue site*
15:00-15:15	**Giuseppe Gallo** *The relevance of biosignatures in siderite-nodules: an example from quaternary continental deposits (Tiberino Basin, Italy)*
15:15-15:30	**Claudia Hahn** *Introducing the potential of antimicrobial materials for human spaceflight activities*
15:30-15:40	**Ralf Moeller** *Summary and closing remarks*
15:40-16:10	**COFFEE BREAK**

	Mars and biosignatures *Chair: Frances Westall* *Co-Chair: Zita Martins*
16:10-16:30	**Martin Lee** *Evidence for silica springs at the surface of Mars from the Nakhla meteorite*
16:30-16:50	**Christian Schroder** *Possible association of ferrous phosphates and ferric sulfates in hydrothermal deposits in Gusev Crater, Mars*
16:50-17:10	**Adrienne Macartney** *ALH84001 carbonates formed by low temperature replacement of plagioclase glass*
17:10-17:30	**Dominic Papineau** *Organic matter in martian meteorites: ingredients for life or contamination?*
	General talk *Chair: Frances Westall*
17:30-18:00	**Euan Clarkson, University of Edinburgh** *On the geology of Edinburgh and its surroundings: death of an ocean, volcanoes, trilobite eyes and the optics of Descartes and Huygens…and more*
19:00	**CONFERENCE DINNER** ***19:00 Reception in the Playfair Library, Old College*** ***19:30 Dinner in the Playfair Library, Old College (map in conference pack)***

Wednesday October 15th

Instrumentation for geochemical and biological exploration in challenging planetary environments

Session supported by STFC Geological Repositories Network (GeoRepNet)

Chair: Muriel Gargaud

Co-Chair: John Parnell

9:00-9:30	**Bettina Haezeleer** *Raman Measurements Under Simulated Martian Conditions*
9:30-9:50	**Cedric Malherbe** *Preparations for the use of Raman spectrometers on Mars*
9:50-10:10	**James Lewis** *Sulfate minerals: A problem for the detection of organic compounds on Mars?*
10:10-10:30	**Paloma Serrano** *Biosignatures of methanogenic archaea by Confocal Raman Microspectroscopy (CRM)*
10:30-11:00	**COFFEE BREAK**
11:00-11:20	**Manish Patel** *Searching for signs of life with the NOMAD spectrometer suite on the ExoMars Trace Gas Orbiter.*
11:20-11:40	**Adam Stevens** *Spatial heterogeneity of biomarkers in analogue environments*
11:40-12:00	**Matt Gunn** *A hyperspectral Imager for Astrobiology*

Searching for biosignatures using space platforms

Chair: Rocco Mancinelli

Co-Chair: Daniela Billi

12:00-12:30	**Petra Rettberg** *Biofilms in space - the experiment BOSS on the EXPOSE R-2 mission*
12:30-14:00	**LUNCH**
14:00-14:20	**Jean-Pierre de Vera** *BIOMEX: Three different steps to approach a systematic determination of habitats and stable biosignatures in space- and Mars-like environments*
14:20-14:40	**Rosa de La Torre** *Lichens survived ground simulation tests before integration on board of the EXPOSE R2 mission*
14:40-15:00	**Corinna Panitz** *Different stress responses of* Deinococcus geothermalis *exposed as biofilms or planktonic cells*
15:00-15:20	**Yuko Kawaguchi** *Tanpopo: Astrobiological exposure and capture experiments of microbes and micrometeorite*
15:20-15:40	**Mickael Baque** *Preservation of cyanobacterial biomarkers after Martian ground-based simulation exposure*
15:40-16:00	**COFFEE BREAK**

Exoplanets and biosignatures

Chair: Kai Finster

Co-Chair: Axel Brandenburg

16:00-16:30	**Lena Noack** *Interior structure and possible habitability of ocean worlds*
16:30-16:50	**Eric Lopez** *Overestimating Eta-Earth: The Importance of Photo-Evaporation*
16:50-17:10	**Duncan Forgan** *Surface Flux Patterns on Planets in Circumbinary Systems, and Potential for Photosynthesis*
17:10-17:30	**William Martin** *Spectropolarimetry, Biosignatures, and the Search for Homochirality*

END OF DAY

Thursday October 16th

Signatures of the prebiotic world
Chair: Paula Lindgren
Co-Chair: Andreas Elsaesser

9:00-9:30	**Zita Martins** *Shock-synthesis of amino acids via the impact of comets*
9:30-9:50	**Kensei Kobayashi** *Formation of Amino Acid Precursors and Nucleic Acid Bases from Simulated Interstellar Media and Their Robustness*
9:50-10:10	**Mita Hajime** *Exposure and Capturer of Amino Acids and their Precursors on the Japanese Experiment Module of the International Space Station*
10:10-10:30	**Rowena Ball** *Hydrogen peroxide as driving agent for replication and evolution in the RNA World*
10:30-11:00	**COFFEE BREAK**

A philosophical perspective on astrobiology
Chair: Frances Westall

11:00-11:30	**Claudio Maccone** *Evolution and SETI (Evo-SETI) as Lognormal Stochastic Processes*
11:30-12:00	**David Duner** *The History and Philosophy of Biosignatures*
12:00-13:30	**LUNCH AND END OF CONFERENCE**

Posters

Poster number	Name & Affiliation	Title
1	Rebecca Siddall *Oundle School*	Mapping Desert Varnish: A Hidden Signature
2	Jan Frösler *University of Duisburg-Essen*	Survival of *Deinococcus geothermalis* under simulated space and Martian conditions
3	Ewa Słaby *Institute of Geological Sciences, PAS*	Phosphates from NWA 2975 shergottite – insights into the evolution of volatiles in Martian magma and their contribution to abiotic systems
4	Ruth-Sophie Taubner *University of Vienna*	Assessing the feasibility to cultivate methanogens under Enceladus-like conditions
5	Rocco L. Mancinelli *BAER Institute, NASA Ames Research Center*	Enceladus: Biosignatures
6	Mark Fox-Powell *University of Edinburgh*	Microbial life in extreme, Mars-relevant brines: liquid water does not imply habitability.
7	Annelie Fiedler *University of Potsdam*	Limits of survival: The effect of mars-like conditions, irradiation and humidity on the vitality of bryophyte species
8	Elliot Curtis-Harper *The Open University*	The anaerobic community of an estuarine environment: an analogue for life on Mars
9	Sohan Jheeta *NoR HGT & LUCA*	Paradigm Shift Hypothesis: a case for RNA's influence on life on Earth
10	Ziga Zebec *University of Vienna*	Iron-oxidising thermoacidophilic archaeon *Metallosphaera sedula*: insights into astrobiological application
11	Frances Westall *CNRS-Centre de Biophysique Moléculaire*	Biosignatures on Mars, a review
12	Tara Pokhriyal *Lovely Professional University*	Effect of heavy metal ions on the antioxidant properties of *Mentha spicata*
13	Stefan Fox *University of Hohenheim*	Formation of Iron Porphyrins Under Putative Prebiotic Conditions
14	Connor Brolly *University of Aberdeen*	Raman spectroscopy: Caution when interpreting organic carbon from oxidised environments
15	Petra Rettberg *DLR*	Tolerance of Archaea and Bacteria against perchlorate
16	Istvan Praet *University of Roehampton*	The Question of Life: Between Anthropology and Astrobiology
17	David E. Bryant *University of Leeds*	Primary sequence control in prebiotic peptide formation *via* chemical and physico-chemical mechanisms.
18	Natasha Nicholson *University of Edinburgh*	Microbially induced rock weathering in the altered fluid dynamics of reduced gravity

19	Rebecca Turk-MacLeod *École Supérieure de Physique et de Chimie Industrielles de la Ville de Paris*	Compartmentalization of the formose reaction to test metabolism-first theories on the origin of life
20	Paula Lindgren *University of Glasgow*	Tracking the earliest water in the solar system via oxygen isotope analyses of carbonates in CM carbonaceous chondrites
21	Maximilian Mora *University of Graz*	ARBEX - Archaeal and bacterial extremophiles onboard the international space station ISS
22	Elias Chatzitheodoridis *National Technical University of Athens*	How to increase the credibility and ease the investigation of biosignatures in TOF-SIMS mass spectra?
23	Elias Chatzitheodoridis *National Technical University of Athens*	Chlorite and other clay minerals on Mars: evidence from Nakhla meteorite
24	Dirk Schulze-Makuch *Washington State University*	Drastic Environmental Change and its Effects on the Habitability of the Terrestrial Planets of our Solar System
25	Susana Direito *University of Edinburgh*	Preservation, stability and recovery of signatures of life from mineral matrixes
26	Ş. Orçun Kalkan *Fundamental and Industrial Microbiology*	UV, Microwave and Heat Shock Resistance in Manganese Requiring *Bacillus sp.* Strains Isolated From Manganese Mine in TURKEY
27	Barbara Cavalazzi *Università di Bologna*	Mineralogical characterization of spring deposits: the importance of the Dallol area (Ethiopia) in astrobiology
28	Kai Finster *Aarhus University*	Wind-eroded silicate as a source of hydrogen peroxide on Mars
29	Kai Finster *Aarhus University*	Structural studies of bacterial ice nucleation proteins and their relevance for atmospheric processes
30	Marina M. Astafieva *Russian Academy of Sciences*	Ancient (PR_1) microorganism colonization of volcanic glasses
31	Jaqueline Gunn *Scottish Universities Environmental Research Centre*	Martian metabolomics: differentiating terrestrial and Martian organic carbon in meteorites
32	Mita Hajime *Fukuoka Institute of Technology*	Protenoid microsphere foremation in the thermal polycondensation of monoammonium malate
33	Maria I. Błęcka *Polish Academy of Sciences*	Influence of volatiles on the composition of the surface and atmosphere of Mars
34	Shin-ichi Yokobori *Tokyo University of Pharmacy and Life Sciences*	Early evolution of genetic code inferred from extant mitochondrial genetic decoding system
35	Urszula Szczepaniak *Polish Academy of Sciences*	Chemical evolution: Towards creation of long unsaturated carbon-nitrogen chains: HC_9N and $C_{10}N$
36	Toby Samuels *University of Edinburgh*	Investigating the rock weathering and carbon utilization capabilities of a microbial community isolated from Whitbian shale cliffs
37	Kirsi Lehto *University of Turku*	Pressurized Martian-like pure CO_2 atmosphere is highly usable for the culturing of cyanobacteria

38	Debajyoti Bose *Yobe State University*	Potentials of Thermophiles for improvement of Agriculture in Rajasthan-India
39	Matthew S Dodd *University College London*	Biosignatures of early life in >3.8Ga Banded Iron Formations?
40	Ana Z. Miller *Universidade de Lisboa*	Morphological features of microorganisms dwelling in an active low-temperature serpentinization site, Cabeço de Vide, Portugal: a possible analogue to early Mars
41	Alexey. F.Topunov *Bach Institute of Biochemistry*	Alternative biochemistry and spreading of extraterrestrial life
42	Ximena Abrevaya *Ciudad Universitaria, Buenos Aires*	Detecting life in other planets: The in situ search using bioelectrochemical systems as biosensors for metabolism detection
43	Karin S. F. Fornazier *São Paulo University*	An eye on biomolecules spectral fingerprints: BEEST and FRACS
44	Henry Strasdeit *University of Hohenheim*	The University of Hohenheim's Master's Programme in Earth System Science: An Opportunity to Specialize in Astrobiology
45	Casey Bryce *University of Edinburgh*	Rock geochemistry drives stress and starvation responses in the bacterial proteom
46	Rachel Cross *Aberystwyth University*	Radiometrically calibrated hyperspectral photoluminescence imaging
47	Erdmann Weronika *Adam Mickiewicz University*	Properties of the Martian magnetic field in the context of a possible Mars exploration.
48	Dennis Höning *DLR*	A Thermal Evolution Model of the Earth Including the Biosphere, Continental Growth and Mantle Hydration
49	Sophie Nixon, *University of Edinburgh*	D-amino acids: constraint on habitability?
50	Björn Huwe *Universität Potsdam*	The evolutionary potential of higher plants
51	Renato dos Santos *Imperial College London*	Mineralogical content, sulfur isotopic composition and carbon, nitrogen and sulfur analysis of Rio Tinto soils: Implications for the detection of biomarkers on Mars
52	Nina Feyh *Institute of Environmental Technology, TU Berlin*	Survival and viability of cells from iron depositing bacterial strains in pretests for the EXPOSE-R2-Experiment
53	Hirofumi Hashimoto *Japan Aerospace Exploration Agency*	Tolerance of Seeds for Low Pressure and Thermal Cycle Environment
54	Annette Brandt *Heinrich-Heine University*	Lichen resistance to extraterrestrial conditions: Viability, ultrastructure and algal growth
55	Alexandra Perras *University of Regensburg*	MASE- Mars analogues for space exploration

Oral Presentations

Monday 13th October

Chair: Petra Rettberg
Co-chair: John Brucato

Extreme among extremes: Salt and sulphur springs of the Dallol (Danakil depression, Ethiopia) and their astrobiological role

[1,2]CAVALAZZI B., [1]BARBIERI R., [3]HAGOS M., [1]CAPACCIONI B., [2]AGANGI A., [1]GASPAROTTO G., [1]PALAZZO Q., [3]KIROS K., [5]GLAMOCLIJA M., [6]ROSSI A.P.

[1]Università di Bologna, Italy, [2]University of Johannesburg, South Africa, [3]University of Mekelle, Ethiopia, [5]Rutgers University, USA, [6]Jocobs University Bremen, Germany

Contact email: barbara.cavalazzi@unibo.it

The Dallol hydrothermal field is a remote volcanic area of the northern Danakil Depression in Ethiopia. Surrounded by a wide saline region, Dallol area is the hottest (average annual temperature: 35°C) and one of the most acidic places ($pH < 1.0$) of the planet. Here, spectacular active and inactive structures (e.g. salt and spring mounds, terraces, metal crusts, concretions) are the result of the complex interactions between sulphuric hot springs, salty solutions, and recrystallization processes driven by hydrothermal waters, degassing, and rapid evaporation. The rusty ground of this hostile landscape has no visible life.

The presence of microbial communities in nearly every type of extreme environment, where liquid water, metabolically suitable carbon, energy, and nutrient sources exist, suggests that unrecognized microbial-ecosystems and -habitats are here waiting to be discovered. Therefore, the Dallol alien environment can potentially host life in a very extreme physical and chemical setting.

Here, we present the preliminary field and analytical results obtained on samples collected during a 2013-field campaign. The geological features of the Dallol and its location close to regional basaltic volcanism of planetary-scale importance make it a suitable analogue to ancient Mars's environments.

Biosignatures valuable for astrobiology: the case of reticulated filaments

A.Z. Miller[1,2], M. Hernández-Mariné[3], V. Jurado[1], J.M. Calaforra[4], P. Forti[5], T. Toulkeridis[6], M.F.C. Pereira[2], A. Dionísio[2] & C. Saiz-Jimenez[1]

[1] *Instituto de Recursos Naturales y Agrobiologia de Sevilla (IRNAS-CSIC), Sevilla, Spain*
[2] *CEPGIST/CERENA, Instituto Superior Técnico, Universidade de Lisboa, Lisboa, Portugal*
[3] *Facultat de Farmacia, Universitat de Barcelona, Barcelona, Spain*
[4] *Department of Biology and Geology, Universidad de Almeria, Almeria, Spain*
[5] *Department of Earth Sciences and Environmental Geology, University of Bologna, Bologna, Italy*
[6] *Universidad de las Fuerzas Armadas (ESPE), Campus Sangolquí, Sangolquí, Ecuador*

Recently reported signs of liquid water on early Mars and volcanic activity suggest that Mars's subsurface could harbour traces of microbial life, making the tracing of life on Earth's subsurface even more compelling. Caves on Earth host an especially interesting variety of mineral-utilizing microorganisms and biological processes, which may be recognized as biosignatures. Subsurface filamentous fabrics, fossil bacteria preserved in minerals, mineralized nano-sized structures and biologically generated textures have been some of the proposed models for extraterrestrial biosignatures.

Intriguing filamentous structures consisting of long reticulated filaments rich in C, Ca, Mn, Fe or Si have been found concealed within speleothems in limestone caves and lava tubes all over the world. They were characterized as mineralized hollow filaments with hexagonal and diamond-shaped chambers resembling honeycombed structures. In this study, microscopy techniques, such as FESEM-EDS, TEM-EDS, CLSM, and ancillary chemical and mineralogical techniques were conducted to recognize biominerals, microbial fabrics or fossil bacteria as possible biosignatures valuable for astrobiology. We focused on enigmatic reticulated filaments found in Ardales cave (Spain), a granite spring water tunnel in Porto (Portugal) and four lava tubes from Canary Islands (Spain), Easter Island (Chile) and Galápagos Islands (Ecuador). Although TEM analyses revealed that in some cases, the mineralized reticulated filaments contain bacterial cells, extensive culturing and molecular biology analyses were elusive to identification. A great research effort is needed in order to ascertain either the affiliation of these sheath-forming microorganisms and their metabolic capabilities, most likely related to the oxidation of mineral compounds, for tracing biological processes on early Earth.

Biogeochemical Cycling and Biogeography in Deep Subsurface Evaporite Deposit Brines

S. PAYLER[1], C. COCKELL[1], S. PALING[2], J. BIDDLE[3], B. SHERWOOD LOLLER[4], U. TRIVEDI[5], J. TELLING[6], K. HUDSON-EDWARDS[7], D. MCLUCKIE[8], T. EDWARDS[8], J. GENIS[8].

[1]UK Centre for Astrobiology, University of Edinburgh, UK.; [2]STFC Boulby Underground Science Facility, Cleveland, UK; [3]College of Earth, Ocean, and Environment, University of Delaware, USA.; [4]Department of Earth Sciences, University of Toronto, Canada.; [5]Edinburgh Genomics, University of Edinburgh, UK.; [6]School of Geographical Sciences, University of Bristol, UK.; [7]Department of Earth and Planetary Sciences, Birkbeck University of London, UK.; [8]Cleveland Potash Ltd, UK.

Little is known about the microbial communities present in brines within deep subsurface evaporite deposits, particularly in relation to biogeochemical processes and the cycling of deep carbon. Here, we examine two spatially separated brine pools present in a 1.1km deep British salt mine in order to elucidate the carbon usage capabilities of the microbial community and its primary carbon sources. Culture and culture-independent methods, including 454 and metagenomics approaches were used alongside a geochemical analysis of the sites. Enrichments were established using a variety of carbon sources. These techniques reveal the community to be predominately composed of aerobic chemoorganotrophic halophiles such as *Halobacteriaceae*, *Salinibacter* and *Halanaerobiales*, suggesting the community relies heavily on fixed carbon sources. Enrichment work indicates that the community is able to utilise a diverse set of carbon sources, including a number of recalcitrant sources. The presence of sequences related to the anaerobic autotroph *Thiohalorhabdus* suggest that part of the carbon budget of the community is supplied by autotrophic metabolisms. These data provide us with the first insights into deep carbon cycling in subsurface hypersaline environments with implications for assessing the habitability of deep hypersaline extraterrestrial environments.

Unambiguous Detection of Microbial Growth with Minimal Assumptions

Samuel Kounaves[1], Dirk Schulze-Makuch[2]

[1] *Department of Chemistry, Tufts University, Medford, MA USA (samuel.kounaves@tufts.edu)*

[2] *School of the Environment, Washington State University, Pullman, WA, USA*

The detection of microbial life beyond Earth must be based on absolutely minimal assumptions about the nature of the organism. The chemistry, structure, and components of such microbes could be significantly different from life on Earth such that they cannot be accurately accounted for in a detection scheme. In addition to requiring water and carbon, there are two properties of microbial life that are likely to be universal and require no prior assumptions, an ability to reproduce itself and the ability to maintain isolation of its cellular processes from the external environment. During reproduction an organism's metabolism will consume and produce, via some membrane, chemical species that will change the surrounding chemical and redox environment. Thus, to detect a microbial organism, a sensing device must be capable of detecting chemical changes, rapidly and free of extraneous or non-biogenic interferences. We describe a chemically based detection technique, dubbed the *Microbial Detection Array* (MiDA) that is designed to provide a response to minute chemical and physical changes occurring in one of two identical chambers via differentially monitored electrochemical sensor arrays. The MiDA detection system makes minimal assumptions about the nature of any life on a planet. Assuming only that, after addition of a small amount of water, the microorganism will replicate and that in the process will produce small changes in its immediate surroundings by consuming, metabolizing, and excreting a number of molecules and/or ionic species.

Microbial production of ice crystals in clouds as a novel atmospheric biosignature

Šantl-Temkiv T.[1], Sahyoun M.[2,3], Korsholm U. S.[2], Sørensen J. H.[2], Nielsen N. W.[2], Kjeldsen H.[1], Ling M.[1], Boesen T.[5], Karlson U. G.[4], Finster K.[1,3]

[1]*Stellar Astrophysics Center*-Department of Physics and Astronomy, [3] *Department of Bioscience,* [4] *Department of Environmental Sciences,* [5] *Department of Molecular Biology and Genetics, Aarhus University, Aarhus, Denmark*

[2] *Danish Meteorological Institute, Copenhagen, Denmark*

A diverse assembly of exoplanets has been discovered during recent decades [1], their atmospheres providing some of the most accessible evidence for the presence of biological activity on these planets. Metabolic gases have been commonly proposed as atmospheric biosignatures [2]. However, airborne microbes are also involved in cloud- and precipitation formation on Earth. Thus, meteorological phenomena may serve as alternative atmospheric biosignatures, for which appropriate observational techniques have yet to be developed.

The atmospheric part of the Earth's water cycle heavily relies on the presence of nucleating particles, which promote the condensation and freezing of atmospheric water, both potentially leading to precipitation. While cloud condensation nuclei are diverse and relatively common, ice nuclei are poorly understood and comparably rare airborne particles. According to current knowledge, most ice nucleation below –15°C is driven by the presence of inorganic dust particles, which are considered inactive at higher temperatures. Biogenic IN are the only reported particles that promote ice formation above –10°C. Some bacteria, e.g. *Pseudomonas syringae*, produce **I**ce **N**ucleation **A**ctive (INA) proteins that are most efficient ice nuclei currently known. These INA bacteria are common in the atmosphere, and may thus be involved in precipitation processes of mixed phase clouds [3].

We investigate the relevance of bacterial INA proteins for atmospheric processes using three approaches: (i) study of the presence of INA bacteria and their INA proteins in the atmosphere, (ii) a detailed molecular and physical study of isolated INA proteins, and finally (iii) a modeling study of the importance of INA proteins for ice-path in clouds as well as their importance for precipitation.

During 14 precipitation events, we observed that 12% of isolated bacteria carried INA genes. INA bacteria had likely been emitted to the atmosphere from terrestrial surfaces, e.g. by convective transport. Additionally, we found INA biological fragments <220 nm in two precipitation samples (199, 482 INA per L), which indicates that in addition to intact cells, the more abundant bacterial fragments could also impact atmospheric processes. In order to study isolated INA proteins, we sequenced the INA gene from one of the isolated bacteria, *Pseudomonas* sp. R10.79. The INA gene will be expressed, purified and introduced into nano-discs. These INA nano-discs will facilitate a detailed molecular and physical study of INA proteins and its ice active properties.

Previous modelling approaches rely on parameterizations based on classical nucleation theory (CNT), e.g. CH08 [4], when introducing INA bacteria into climate models. Instead, we used an experimentally derived parameterization HAR13 developed by Hartmann et al [5], when introducing bacteria into a 1-d operational weather model HIRLAM [6] (Fig 1). Comparing HAR13 to CH08 parameterization, we found that HAR13 was more sensitive to the change of bacterial densities. While CH08 is a function of the ice nuclei size, HAR13 is a function of the number of INA protein complexes on the cell surface, which appears to be a more important parameter than cell size. We suggest that the study of individual INA proteins and their complexes both alone and on cell surfaces will lead to a better understanding of ice nucleation by INA bacteria.

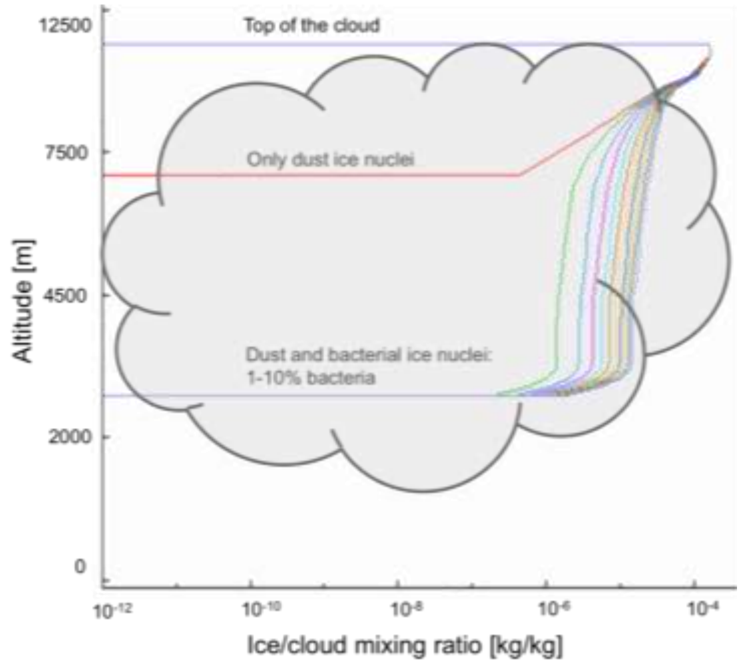

Fig. 1 An example of an ice vertical profile in a mixed phase cloud showing the impact of different ice nuclei on cloud structure.

[1] A. W. Howard, *Science 340* (2013)
[2] S. Seager, M. Schrenk, and W. Bains, *Astrobiology 12(1)* (2012)
[3] O. Möhler, P. J. DeMott, G. Vali, and Z. Levin, *Biogeosciences 4* (2007)
[4] J. P. Chen, A. Hazra, and Z. Levin, *Journal of Atmospheric Sciences 51* (2008)
[5] S. Hartmann, S. Augustin, T. Clauss, H. Wex, T. Šantl-Temkiv, J. Voigtländer1, D. Niedermeier, and F. Stratmann, *Atmospheric Chemistry and Physics 13* (2013)
[6] P. Unden, et al HIRLAM-5, *Scientific Documentation* (2002)

Boundaries for prokaryotic growth in multiple-stress habitats

Jesse P. Harrison, Nicolas Gheeraert, Dmitry Tsigelnitskiy, Luke Dobinson, Kenneth Freeman, Ross McKenzie, Dale Wyllie, Sophie L. Nixon, Charles S. Cockell

UK Centre for Astrobiology, School of Physics and Astronomy, University of Edinburgh, Edinburgh, EH9 3JZ, Scotland

The physical and chemical limits for life are defined by diverse stress parameters, such as high temperatures, pH and low water availability. Although it is frequently the net effect of these parameters that defines the boundary space for life, we are only beginning to investigate how multiple-stress conditions shape the biological permissiveness of extreme environments. In this study, the limits for life under combined extremes of temperature, pH, salinity and pressure are explored, using 3D 'maps of habitability' constructed using growth data published for prokaryotic strains.

In addition to illustrating how interactions between extremes may broaden or constrain the habitable window on Earth, the resulting maps reveal a fundamental lack of information on microbial responses and adaptations to multiple environmental stressors (Harrison *et al.*, 2013). Further analyses of the data are also enabling us to quantitatively investigate whether distinct groups of isolates (e.g., aerobic vs. anaerobic strains) differ in terms of their growth ranges and ability to tolerate diverse stress parameters, and whether such differences are thermodynamically predictable.

References:

Harrison JP *et al.* (2013) The limits for life under multiple extremes. *Trends in Microbiology* 21: 204–212.

Impact shocked rocks as protective habitats on an anoxic early Earth

Casey Bryce[1], Gerda Horneck[2], Elke Rabbow[2], Howell Edwards[3,4] and Charles Cockell[1]

[1]UK Centre for Astrobiology, School of Physics and Astronomy, University of Edinburgh, Edinburgh, Scotland, UK

[2]German Aerospace Centre DLR, Institute of Aerospace Medicine, Cologne, Germany

[3]Centre for Astrobiology and Extremophiles Research, School of Life Sciences, University of Bradford, Bradford, UK

[4]Department of Physics and Astronomy, Space Science Research Centre, University of Leicester, Leicester, UK

Microbial exposure to intense UV irradiation leads to death and significant damage to biomolecules, which also severely diminishes the likelihood of detecting signatures of life. On Earth, microorganisms living under intense ultraviolet (UV) radiation stress often adopt endolithic lifestyles, growing within cracks and pore spaces in rocks. Using the European Space Agency's "EXPOSE-R" facility, we show that porous rocks shocked by asteroid or comet impacts provide adequate protection for phototrophs and their biomolecules during 22 months of UV radiation exposure outside the International Space Station. The UV spectrum used approximated the high-UV flux on the surface of planets lacking ozone shields such as the early Earth. These data provide a demonstration that endolithic habitats can provide a refugium from the worst-case UV radiation environments on young planets and an empirical refutation of the idea that early intense UV radiation fluxes would have prevented phototrophs (without the ability to form microbial mats or produce UV protective pigments) from colonizing the surface of early landmasses. I will also discuss the implications of this work for impact craters as an Astrobiologically significant habitat.

Chair: Martin Lee
Co-chair: Jean-Pierre de Vera

Microhabitats for microbial life in a liquid natural asphalt lake and their relevance as an astrobiological analog to Titan

Dirk Schulze-Makuch[1,2], Rainer Meckenstock[3], and Shirin Haque[4]

1 School of the Environment, Washington State University, Pullman, WA 99164, USA,
2 Center of Astronomy and Astrophysics, Technical University Berlin, 10623 Berlin, Germany
3 Biofilm Center, University Duisburg-Essen,, 45141 Essen, Germany
4 Dept. of Physics, University of Trinidad and Tobago

We report on a microhabitat of bacteria and archaea contained in miniscule water droplets within a natural liquid asphalt lake on the island of Trinidad. High salinity and water-stable isotopes of the droplets indicate a deep subsurface origin (Meckenstock et al., 2014). Not only does the large surface area of the droplets represent an underestimated potential for biodegradation of oil away from the oil-water transition zone, but the geological scenario may provide a suitable analog to Titan where heated water-ammonia mixtures from the deeper subsurface (e.g., “ground-water” or water from a deep subsurface ocean) may transect Titan’s hydrocarbon lakes.

Reference: Meckenstock et al. (2014) Science

Electric Cable Bacteria and Mineralogical Signatures of Life

Anja Bauermeister[1], Jeff Schramm[2], Yuri Gorby[1,2]

[1] *Dept. of Civil and Environmental Engineering, Rensselaer Polytechnic Institute, Troy, NY*
[2] *Dept. of Biology, Rensselaer Polytechnic Institute, Troy, NY*

‘Electric cable bacteria’ are organisms of the family *Desulfobulbaceae* that exhibit a novel method of electron transport. Cells form conductive filaments that function like electric wires, transferring electrons over distances of more than 1 cm from deep sulfidic sediments to oxygen or other electron acceptors near the soil/water interface. The rate of electron transfer across redox boundaries far exceeds that of diffusion limited processes and generates pH gradients that can significantly influence geochemical reactions, leading to the formation of distinct mineralogical profiles unlikely to be created by abiotic means. Our research seeks to address the question whether these mineralogical profiles can be regarded as signatures of life. We will test whether the mineral banding patterns can be preserved in the rock record and study how the mineral transformation processes are affected by the geochemical environment. Understanding the mechanism of charge transfer and the prevalence of cable bacteria in diverse environments can help to broaden our definition of habitability of the subsurface.

UVC-induced photodamage and its attenuation by co-occurring stressors in the photobionts of the astrobiologically relevant lichens *Buellia frigida* and *Circinaria gyrosa*

Joachim Meeßen[1], Theresa Backhaus[1], Marina Mrkalj[1], Frauke Schürmann[1], Rosa de la Torre[2], Jean-Pierre de Vera[3], Sieglinde Ott[1]

[1]*Institut für Botanik, Heinrich-Heine-Universität, 40225 Düsseldorf, Germany*
[2]*Instituto Nacional de Técnica Aeroespacial, 28850 Torrejón de Ardoz, Madrid, Spain*
[3]*Institut für Planetenforschung, Deutsches Zentrum für Luft- und Raumfahrt, 12489 Berlin, Germany*

Previous studies investigated the viability and photosynthetic activity of lichen photobionts after exposure to simulated or real space parameters. They consistently found high viability and recovery of photosynthetic activity (de Vera et al. 2003, 2004a, 2004b, de la Torre et al. 2010, Onofri et al. 2012, Sánchez et al. 2012, 2014, Brandt et al. 2014, *in press*). To investigate such resistance in detail, we exposed metabolically active photobionts of two lichens, *Buellia frigida* and *Circinaria gyrosa*, to UVC_{254nm} alone and in combination with desiccation and cold. The effect was examined by chlorophyll *a* fluorescence and characterised by quantum yield reduction and changes in non-photochemical quenching. The results indicate a strong impairment of photosynthetic activity, photo-protective mechanisms and overall photobiont vitality when being irradiated in the isolated and metabolically active state. Nonetheless, co-occurring stressors as desiccation and subzero-temperatures can attenuate the UVC-damage.

Our experiments stress the high susceptibility of photobionts towards UVC-exposure but also demonstrate that desiccation and cold confer an additive, protective effect on the investigated photobionts. Besides other protective mechanisms (anhydrobiosis, morphological-anatomical traits, secondary lichen compounds) the finding that the photobionts' reaction to one stressor attenuates the effect of another one – even if it is a non-terrestrial stressor as UVC – may be one piece of the puzzle to explain the consistently high resistance of lichens observed in previous astrobiological studies.

Anaerobic microorganisms in analogue environments: MASE – an overview

Petra Schwendner[1] and the MASE team[2]

[1] *UK Centre for Astrobiology, School of Physics & Astronomy, University of Edinburgh, Edinburgh, UK*

[2] http://mase.esf.org/consortium.html

One of the major yet unsolved questions is whether life is unique to our planet. Recent data indicate a plausibility to contemplate microbes existing in seemingly hostile places other than Earth with Mars representing the most prominent example. Despite the fact that the geologic and climatic conditions prevalent on Mars bear a challenge for the survival and evolution of Earth-like organisms, past and possible present Mars may have hosted conditions that could be habitable. Therefore, the MASE (Mars Analogues for Space Exploration) project was proposed to gain knowledge on Mars habitability and on adaptation of anaerobic life forms to extremes by analysing Mars analogues on Earth while also allowing to optimise mission operations and life detection. In particular, MASE is the:

i) Isolation and characterization of anaerobic microorganisms from selected sites that mimic environmental conditions on early Mars.

ii) Study of their responses to realistic combined environmental stresses that might have been experienced in habitable environments on Mars.

iii) Investigation of their potential for fossilisation on Mars and their detectability by carrying out a systematic study of artificially fossilised organisms exposed to known stresses.

This European project aims at advancing our ability to assess the habitability of Mars and whether the combined environmental stresses experienced there are compatible with life and whether a record of that life could ever be detected.

Infrared spectral investigations of UV irradiated nucleobases adsorbed on mineral surfaces

John Brucato[1], Teresa Fornaro[1,2],Malgorzata Biczysko[3] and Vincenzo Barone[1]

[1]*INAF – Astrophysical Observatory of Arcetri, Firenze, Italy*
[2]*Scuola Normale Superiore, Pisa, Italy*
[3]*CNR - Institute of Chemistry of Organometallic Compounds - UOS Pisa, Pisa, Italy*

Spectroscopic studies of UV radiation on biomolecules such as nucleobases found in heterogeneous environments are particularly relevant in prebiotic chemistry to unravel the role of minerals in the transformation/preservation of biomolecules in abiotic environments. Minerals may have a pivotal role in the prebiotic evolution of complex chemical systems, mediating the effects of electromagnetic radiation, influencing the photostability of biomolecules, catalysing important chemical reactions and/or protecting molecules against degradation. Studies on the photodegradation of biomolecules adsorbed on minerals have applications also in the life detection context to identify potential biomarkers for future space mission and hence to develop suitable sample-extraction protocols for bioanalytical instruments [1]. Moreover, the characterization of the spectroscopic features of biomolecules-mineral complexes provides a support in remote sensing spectroscopy for detecting organic compounds on planetary surfaces or cometary grains and asteroid surfaces.

In particular, nucleobases are prebiotically relevant molecules to investigate, being coding components of nucleic acids, and are of interest also from the standpoint of the preservation of biological systems in space conditions. It is believed that nucleobases might have played a critical role at the dawn of life due to their photoprotective properties. Indeed, several studies on the photodynamics of nucleobases suggest that their structure could have been naturally selected for the ability to dissipate electronic energy through ultrafast photophysical decay [2]. In this context we will present laboratory results on UV photostability of nucleobases adsorbed on magnesium oxide and forsterite minerals and analysed with infrared spectroscopic [3,4]. However, spectroscopic data may be rather intricate when dealing with such complex systems, which are characterized by various types of intermolecular interactions influencing vibrational frequencies. Misleading assignments based on gas-phase data might occur. Therefore a strong synergy between experimental and computational studies is often indispensable for accurate spectroscopic assignments. For this reason we will show a general, reliable and effective computational protocol for analysing infrared spectra of nucleic acid bases - solid-support complexes [5].

[1] T. Fornaro, J. R. Brucato, A. Pucci and S. Branciamore, *Planetary and Space Science*, **86,** 75 (2013).

[2] T. Gustavsson, Á. Bányász, E. Lazzarotto, D. Markovitsi, G. Scalmani, M. J. Frisch, V. Barone and R. Improta, *J. Am. Chem. Soc.*, **128**, 607 (2006).

[3] T. Fornaro, J. R. Brucato, E. Pace, M. Cestelli Guidi, S. Branciamore and A. Pucci, *Icarus*, **226**, 1068 (2013).

[4] T. Fornaro, J. R. Brucato, S. Branciamore and A. Pucci, *International Journal of Astrobiology*, **12,** 78 (2013).

[5] T. Fornaro, M. Biczysko, S. Monti and V. Barone, *Phys. Chem. Chem. Phys.*, DOI: 10.1039/C3CP54724H, (2014).

Ferromagnesian rocks in association with carbonates as a signature of life

Marie-Paule Bassez

IUT, Université de Strasbourg, 72 route du Rhin, 67400 ILLKIRCH, France.
marie-paule.bassez@unistra.fr http://chemphys.u-strasbg.fr/mpb

Rocks such as peridotites and basalts contain ferromagnesian minerals. They evolve in the presence of H2 O and CO2. Some reactions are exothermic and produce carbonates. Heat locally released, induces production of H2 . H2 is also produced in water radiolysis. Combination of heat, H2 and CO2 leads to a local formation of CO in an hydrothermal process. With N2 and with an activation source arising from cosmic radiation or from radionuclides, ferromagnesian rocks might evolve towards peptide like macromolecules such as those observed by Kensei Kobayashi in atmosphere simulation experiments.
Ferromagnesian rocks reactions are described. It is shown that an observed association of ferromagnesian rocks and carbonates might be a signature for abiotic syntheses of prebiotic molecules. They might be germs of life everywhere in the universe. This "pantaspermie" for life is discussed for Mars. This chemical evolution from a rocky world to a prebiotic world has first been proposed in 2008 and was then presented in conferences.

Articles

BASSEZ MP (2008a) Synthèse prébiotique dans les conditions hydrothermales. CNRIUT'08.
BASSEZ MP (2008b) Prebiotic synthesis under hydrothermal conditions. OLEB 39(3–4):223 (2009); proceedings of the 2008 ISSOL conference, Firenze.
BASSEZ MP (on line 2008) Prebiotic synthesis under hydothermal conditions. C. R. Chimie, Académie des Sciences, Paris 12(6-7): 801 (2009).
BASSEZ MP (2014) A chemical evolution from a rocky world to a prebiotic world.

Oral Presentation

BASSEZ MP (2013) Geochemical origin of biological molecules. EGU OralPS8.1, EGU2013-22, 07-12/04/2013

Recovery of Amino Acids from Mineral Surfaces – Implications for Life Detection Strategies

A. Elsaesser[1]*, J. Aerts[2], S.O.L. Direito[3], R. dos Santos[4], Z. Martins[4], P.Ehrefreund[1]

[1]*University Leiden, dThe Netherlands,*
[2]*VU University Amsterdam, The Netherlands,*
[3]*University of Edinburgh, United Kingdom,*
[4]*Imperial College London, United Kingdom*
*(a.elsaesser@umail.leidenuniv.nl)

Abstract

As important biomarkers on Earth, amino acids are one of key organic compounds in the search for life on other planets. Their interaction with inorganic and mineral and surfaces is of special interest to the astrobiology and planetary science community. Amino acids are known to degrade under UV- and ionizing radiation or secondary processes, e.g. oxidation, unless shielded or protected. Mineral substrates, and in particular clay minerals, can adsorb organic compounds efficiently and may have played a central role in the evolution of life. Rock formations, rich in clay minerals, are therefore a priority target for life detection strategies.

The properties of mineral surfaces strongly influence the interaction with biomarkers such as amino acids. Understanding those interactions is crucial in order to efficiently extract and detect amino acids from soil samples. By measuring the retention properties of minerals (including clays) after spiking with known concentrations of amino acids will allow us to determine key extraction parameter and will enable us to improve strategies for amino acid recovery.

Optimised extraction methods and detection techniques will be of great interest for upcoming Mars exploration missions in order to increase detection sensitivity and specificity.

Tuesday 14th October

Chair: Martin Lee
Co-chair: Jean Pierre de Vera

Demonstrating deep biosphere activity in the geological record of lake sediments

John Parnell[1], Sean McMahon[1] & Joe Michalski[2]
[1]*School of Geosciences, University of Aberdeen, Aberdeen AB24 3UE, UK*
2Natural History Museum, London, UK
J.Parnell@abdn.ac.uk

The recognition of an extensive deep biosphere on Earth, and the advantages of a deep biosphere for putative life on other planets, have contributed to the serious consideration of deep biosphere targets in the search for evidence of life on Mars. The lacustrine infills of impact craters on Mars are an especially attractive target, as they may be preferred sites of thermal activity and nutrient accumulation.

A study in the Devonian Orcadian Basin, Scotland, sought to show that lake basins can also hold a record of a deep biosphere. In the middle of the basin is an inlier of the underlying basement, comparable in nature to the central uplift found in larger impact craters. As in craters, the basement inlier was a focus of hydrothermal activity during sedimentation. Further hydrothermal activity occurred after the cessation of sedimentation. Like the surface of Mars, the basin was sulphate-rich, and it shows widespread evidence for sulphate precipitation at the surface and sulphide precipitation in the subsurface. The distribution of sulphides and their isotopic composition indicate several settings for subsurface biological activity. Hydrothermal activity occurred at and below the contemporaneous sediment surface, focussed around the basement inlier. Temperatures were <80 °C, so within the tolerance of thermophile microbes. Later hydrothermal mineralization by pyrite-bearing veins cut all rocks, indicating that they post-dated sedimentation. These observations can be translated to the exploration of Mars. The focus of hydrothermal activity around a basement inlier is especially pertinent, as this feature is found in impact craters and identified as a desirable target on Mars.

Chair: Gerda Horneck
Co-chair: Lena Noack

"The devil is in the detail" - understanding bacterial spore resistance towards plasma sterilization

Marina Raguse[(1)], Marcel Fiebrandt[(2)], Benjamin Denis[(2)], Katharina Stapelmann[(2)], Peter Awakowicz[(2)], Günther Reitz[(1)], and Ralf Moeller[(1),]*

[(1)]German Aerospace Center (DLR e.V.), Institute of Aerospace Medicine, Radiation Biology Department, D - 51147 Cologne (Köln), Germany, [(2)]Ruhr University Bochum, Institute for Electrical Engineering and Plasma Technology (AEPT), D-44780 Bochum, Germany.

*Corresponding/presenting author: German Aerospace Center (DLR e.V.), Institute of Aerospace Medicine, Radiation Biology Department, Research Group 'Astrobiology', D - 51147 Cologne (Köln), Germany, Phone: +492203603145, Fax: +49220361970, Email: ralf.moeller@dlr.de

Microbial contamination arising from spacecraft exploration harbors the distinct potential to impact the development and integrity of life-detection missions on planetary bodies such as Mars and Europa. Those missions going into space are subjected to strict regulations. In the context of the planetary protection guidelines, established by the Committee of Space Research (COSPAR) in 1967, it is essential to reduce or eliminate the biological burden on flight hardware prior to launch in order to prevent cross contamination of celestial bodies with environmental or human-associated microorganisms. Current sterilization procedures have reached their limit as they usually require elevated temperatures and prolonged exposure times, which are likely to introduce damage to advanced flight hardware materials. Methods for sterilizing surfaces are generally based upon chemical and/or physical, mechanical, and thermal processes (e.g., high pressure, high temperature, UV, and gamma irradiation). Many of these processes suffer from disadvantages due to cost, difficulty of user-acceptance, formation of residues on surfaces, changes in surface properties, and acquired microbial resistances.

For several years a number of activities in the field of sterilization of heat sensitive materials by means of non-thermal plasmas are known. Plasma sterilization methods are characterized by the use of gas or gas mixtures that are partially excited by an applied electric field. Accordingly, multiple plasma components are individually bactericidal and make plasma suitable as a new method for decontamination and sterilization even against highly resistant bacterial endospores of *Bacillus subtilis*. Here, we will present our recent findings on the molecular mechanisms involved in the spore resistance to plasma sterilization. During spore revitalization, DNA damage accumulated during the dormant spore stage is the subject of a variety of different repair systems. Deficiencies in repair genes of non-homologous end-joining, spore photoproduct lyase, or nucleotide excision repair led to a significant decrease in spore resistance to low pressure argon plasma.

Life on Venus: radiation hazards to an aerial biosphere

Lewis R. Dartnell[1], Tom Andre Nordheim[2,3], Laurent Desorgher[4], Andrew J Coates[2,3], Geraint H Jones[2,3]

[1] Space Research Centre, University of Leicester, Leicester, LE1 7RH
[2] Mullard Space Science Laboratory, University College London, Dorking, Surrey, RH5 6NT
[3] Centre for Planetary Sciences at UCL/Birkbeck, University College London, Gower Street, London, WC1E 6BT
[4] Laboratory for Particle Physics, Paul Scherrer Institute, Villigen, 5232, Switzerland

Although utterly incompatible with life on its surface, the environmental conditions high in the atmosphere of Venus offer a potentially habitable niche for astrobiology. Within the global cloud layers the droplets are pH 0 with sulphuric acid. Terrestrial polyextremophiles able to resist the combined hazard of high temperature and acidity grow at pH 0 only up to temperatures of 65°C, which sets the floor of a potential Venusian aerial biosphere at around 52 km altitude. High in the atmosphere, a Venusian biosphere would be exposed to the peak flux of ionising radiation from cosmic rays, and in particular to the sporadic but intense bursts of radiation from solar energetic particle events. Here we model the extensive cascades of secondary particles propagating down through the atmosphere from energetic galactic cosmic ray (GCR) and solar energetic particle (SEP) primaries in order to calculate the radiation environment and the biological hazard it presents in this habitable zone. The 1859 'Carrington Event' is taken as a worst-case scenario for sporadic but extremely high flux solar particle events.

Expected Biosignatures from Increases in Entropy and Disequilibrium

Dirk Schulze-Makuch[1,2]
Joop M. Houtkooper[2]

[1]*School of the Environment, Washington State University, Pullman, WA 99164, USA*
[2]*Center for Astronomy and Astrophysics, Technical University Berlin, 10623 Berlin, Germany*

The gross energy conversion process of a planet involves the absorption of sunlight and the emission of thermal radiation. The energy balance is further contributed to by the loss of internal heat of the planet and by the conversion of energy involved in nonequilibrium chemical reactions.

Biosignatures, which may derive from large-scale energy conversion processes such as photosynthesis usually occur with diurnal and seasonal, and sometimes even geological variations (of e.g. the amount of CO_2 in the atmosphere), which makes it harder to attribute them to a life process.

The case is clear for Earth with a strong disequilibrium between dioxygen and methane. However, the much smaller disequilibria present in the atmospheres of Mars, where oxygen and methane co-occur with indications of seasonal variations, and Venus, where a sulfur cycle operates with reducing and oxidizing sulfur compounds, which could be due to atmospheric circulation only, are examples where a firm conclusion, whether the observed disequilibrium is caused by the inclusion of life processes, cannot be made at present.

An increase in entropy and non-equilibrium reactions can also be detected on the microscale. While chemical reactions are usually occurring in a way to release the most energy given a suitable catalyst, metabolic reactions are generally fine-tuned, to occur in various steps and release easily controllable small energy quanta. We consider this step-wise metabolic process as one universal biosignature of life, but one which can only be detected with in-situ life detection techniques.

Chair: Ralf Moeller

Isolation of radiation resistant bacteria from the Antarctic Dry Valleys by pre-selection and the correlation between radiation and desiccation resistance.

Michaela Musilova[1], Gary Wright[2], John M. Ward[3] and Lewis R. Dartnell[4]

1 Bristol Glaciology Centre, School of Geographical Sciences, University of Bristol, Bristol
2 Department of Engineering and Applied Science, Cranfield University, Shrivenham, Swindon
3 Department of Biochemical Engineering, University College London, London
4 Space Research Centre, Department of Physics & Astronomy, University of Leicester, Leicester

Corresponding author:
Email: m.musilova@bristol.ac.uk

Extreme radiation resistant microorganisms can survive doses of ionising radiation far greater than are present in the natural environment. Radiation resistance is believed to be an incidental adaptation to desiccation resistance, as both hazards cause similar cellular damage. Desert environments are, therefore, promising targets to prospect for new radiation resistant strains. In this study, radiation resistant microbes were isolated using gamma–ray exposure pre-selection from the extreme cold desert of the Antarctic Dry Valleys (a Martian surface analogue). The surviving strains were identified by 16S rRNA gene sequencing as members of five genera: *Rhodobacter*, *Herbaspirillum*, *Hymenobacter*, *Staphylococcus* and *Halomonas*. They are related to strains previously found in Antarctica, other desert soils (Sonoran, Xinjiang and Tataouine) and spacecraft assembly clean-rooms. Halomonads were the most numerous survivors of the highest irradiation exposures. They were studied here for both their desiccation and irradiation survival characteristics for the first time. The association between desiccation and radiation resistance has not been investigated quantitatively before for a broad diversity of microorganisms. Thus, a meta-analysis of scientific literature was conducted to gather a larger dataset. A strong correlation was found between desiccation and radiation resistance, indicating that an increase in the desiccation resistance of five days corresponds to an increase in the room temperature irradiation survival of 1 kGy. Irradiation at -80°C (representative of average Martian surface temperatures) increases the microbial radiation resistance nine-fold. Consequently, the survival of the cold, desiccation and radiation resistant organisms isolated here has implications for the potential habitability of the Martian surface.

Studies on Astrobiology with Particular Reference to Cometary Panspermia

Tareq L Omairi, (Hon. Cardiff) M. Wainwright

The University of Sheffield/ Department of Molecular Biology and Biotechnology

Sponsored By the Higher Committee of Education Development in Iraq (HCED)

Cometary Panspermia suggests that life is exchanged throughout the universe between planets continuously. This study attempts to prove this theory by collecting and analysing stratospheric and meteorite samples and look for microbes or microbial fossils within it using Scanning Electron Microscopy and EDAX. Biological findings were reported in some of the stratospheric samples obtained from multiple balloon launches, with most appearing to be single cellular microbes, and few showing unique morphologies unsimilar to any know terrestrial species.

Possible fossilised bacterial biofilm was also found within one Martian meteorite. Terrestrial rock samples also were examined for endolithic microbes that could be ejected to space, and various common species were isolated and identified. Simulations for microbes within comets composed of ice and solid particles were made to evaluate resistance against ultraviolet radiation, protection against radiation was found to be efficient when solid particles were incorporated into ice, even if those particles are significantly smaller in diameter that the microbes it protects. Indications for biofilm formation with the aid or inorganic nanoparticles are also reported. We are also trying to prove whether UV can be utilized as an indirect light source to provide energy for photosynthetic microbes under certain conditions.

Ignicoccus hospitalis shows high radiation tolerance although never exposed to it in its natural habitat

Dagmar Koschnitzki[a]*, Kristina Beblo-Vranesevic[a], Harald Huber[b], Reinhard Rachel[c], Reinhard Wirth[b], Petra Rettberg[a], Günther Reitz[a]

[a]*Department of Radiation Biology, Institute of Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany*
[b]*Institute for Microbiology and Archaea Center, Faculty of Biology and Preclinical Medicine Natural Sciences III,*
University of Regensburg, Regensburg, Germany
[c]*Centre for EM / Anatomy, Faculty of Biology & Preclinical Medicine, University of Regensburg, Regensburg, Germany*
**Corresponding author: E-mail: dagmar.koschnitzki@dlr.de*
dagmar.koschnitzki@stud.uni-regensburg.de

One of the burning questions in astrobiology is how life has formed and developed on Earth, and how it is distributed in the universe. If hyperthermophilic microorganisms were the first inhabitants on Earth, are today´s hyperthermophiles also able to tolerate harsh environmental conditions as they occurred on early Earth? For first answers to this question survival rates of the Crenarchaeon Ignicoccus hospitalis were determined after exposure to UV-C and ionizing radiation, respectively. I. hospitalis showed the same ability to survive high fluences of UV-C, as some other hyperthermophiles, but its very unusual high ionizing radiation tolerance (S (10 kGy) = $4x10^{-2}$) indicates

highly effective, and to date unknown repair mechanisms needed for proper evolution and distribution of life. RAPD (randomly amplified polymorphic DNA) and agarose gel electrophoresis qualitatively confirmed changes in the genomic DNA after irradiation treatment. Future experiments will focus on the investigation of repair kinetics, which might help to uncover yet unknown DNA repair mechanisms, and potential interactions between DNA repair mechanisms triggered by external stimuli.

Potential of Cupriavidus metallidurans CH34 for biomining from lunar-like basalt by determining the molecular mechanisms behind microbe-mineral interactions

Bo Byloos, Rob Van Houdt, Nico Boon and Natalie Leys

Microbe-mineral interactions have become of interest for space exploration as microbes can biomine useful elements from extra-terrestrial materials for use as nutrients in a life support system. Therefore, this research is aimed to identify the molecular mechanisms and assess the influence of space conditions on these microbe-mineral interactions on basalt.

Survival and physiology of the bacterium *Cupriavidus metallidurans* CH34 was monitored over several months, in mineral water, with and without basalt, by plate counts, flow cytometry, ICP-MS and microscopy. To study the influence of micro-gravity on these interactions this setup was also send as a flight experiment onboard the Russian BION capsule.

The results show that CH34 was able to survive in mineral water, in the presence and absence of basalt. The viable cells concentration remained stable, but the cultivable fraction dropped to 10% after 3 months in water with and without basalt. Chemical analysis showed that in water without basalt the phosphate concentration declined. In the basalt containing water phosphate also declined but the concentration of copper, magnesium and calcium increased. CH34 also attached to the basalt rock and formed a biofilm. To know more about the molecular processes behind these interactions, additional physiological and molecular analysis is ongoing. Upon the return of the flight experiment also the impact of space conditions on the survival and biofilm formation will be assessed.

Analysis of *Bacillus subtilis* spore germination in high-salinity environments

Katja Nagler[1], Ralf Moeller[1], Peter Setlow[2], Petra Rettberg[1], Guenther Reitz[1]

[1]German Aerospace Center (DLR), Institute of Aerospace Medicine, Radiation Biology Department, Research Group Astrobiology, Cologne (Köln), Germany
[2]University of Connecticut Health Center, Department of Molecular, Microbial and Structural Biology, Farmington, Connecticut, 06030-3305, USA

Upon nutrient depletion, some bacteria such as *Bacillus subtilis* can form metabolically inert and highly resistant endospores capable of surviving space travel. As *Bacillus* sp. were shown to be a common bioload on space crafts and vehicles, the conversion of spores back into growing cells (i.e. germination) under extraterrestrial conditions is an important issue for planetary protection. On Mars and other celestial bodies, liquid water, as a prerequisite of life as we know it, is often expected to be tightly associated with salts, thus constituting high-salinity environments. Hence, *B. subtilis* spore germination in the presence of high salt concentrations was investigated. Using various spectrophotometric, fluorometric, microscopic, and cultivating techniques it could be shown that increasing salt concentrations decrease germination efficiency, although some spores still initiated germination and metabolism despite very high NaCl concentrations (> 4 M). Other salts also inhibited germination, albeit to different extents. The exact mechanisms of salt inhibition are not yet clear, but transporter proteins are likely inhibition targets. These results may provide useful insights on how organisms cope with extreme environments and on potential risks of forward contamination of other planets and moons with terrestrial microbes.

BIOMEX (Biology and Mars Experiment): Preliminary results on Antarctic black cryptoendolithic fungi in ground based experiments.

Claudia Pacelli (University of Tuscia, Viterbo, Italy), Laura Selbmann (University of Tuscia, Viterbo, Italy), Silvano Onofri (University of Tuscia, Viterbo, Italy), Jean-Pierre Paul de Vera (Deutsches Zentrum fur Luft- und Raumfahrt e.V. (DLR), Germany)

The main goal for astrobiologists is to find traces of present or past life in extraterrestrial environment or in meteorites. Biomolecules, such as lipids, pigments or polysaccharides, may be useful to establish the presence of extant or extinct life (Simoneit, B et al., 1998). BIOMEX (Biology and Mars Experiment) aims to measure to what extent biomolecules, such as pigments and cellular components, preserve their stability under space and Mars-like conditions. The experiment has just been launched in the space and will be exposed on EXPOSE-R payload to the outside of the International Space Station (ISS) for about 2 years. Among a number of extremophilic microorganisms tested, the Antarctic cryptoendolithic black fungus *Cryomyces antarcticus* CCFEE 515 was included in the experiment. The fungus, living in the airspaces of porous rocks, was already chosen in previous astrobiological investigation for studying the interplanetary transfer of life via meteorites. In that context, the fungus survived 18 months of exposure outside of the ISS (Onofri al., 2012); for all these reasons it is considered an optimal eukaryotic model for astrobiological exploration. Before launch dried samples were exposed, in ground based experiments, to extreme conditions, including vacuum, irradiation and temperature cycles.Upon sample re-hydration and survival analysis, including colony forming ability, Propidium MonoAzide (PMA) assay-coupled quantitative PCR (Mohapatra and La Duc, 2012) all the test systems survived, neither any DNA damage was detectable. Our analyses focused also on mineral-microorganisms interactions and stability/degradation of typical fungal macromolecules, in particular melanin, when exposed to space and simulated Martian conditions, contributing to the development of libraries of biosignatures in rocks, supporting future exploration missions.

Mohapatra, B. R., & La Duc, M. T. (2012). Evaluation of fluorescence in situ hybridization to detect encapsulated Bacillus pumilus SAFR-032 spores released from poly (methylmethacrylate). *Microbiology and immunology*, *56*(1), 40-47.

Onofri, S., de la Torre, R., de Vera, J. P., Ott, S., Zucconi, L., Selbmann, L., & Horneck, G. (2012). Survival of rock-colonizing organisms after 1.5 years in outer space. *Astrobiology*, *12*(5), 508-516.

Simoneit, B. R., Summons, R. E., & Jahnke, L. L. (1998). Biomarkers as tracers for life on early Earth and Mars. *Origins of Life and Evolution of the Biosphere*, *28*(4-6), 475-483.

Grappling hooks: The life style and ultrastructure of the SM1 Euryarchaeon which thrives in a Mars analogue site

Alexandra Perras[1] and Christine Moissl Eichinger[1]

[1]*Institute for Microbiology and Archaea Center, University of Regensburg*

Knowledge about anoxic microorganisms thriving in Mars analogue sites is sparse and needs to be expanded in comprehensive studies. The MASE (Mars analogues sites for space exploration) project is focused on investigating how anaerobic microorganisms from such sites react on stress conditions which could also occur on Mars. Five field sites which seem to resemble Martian conditions were chosen for further investigation including a cold sulfidic spring in Germany. The spring harbors bacteria and archaea, which are highly adapted to anoxic conditions, low nutrient sources and sulfur as one of the major energy-yielding compounds. The entire microbiome of the spring is dominated by one archaeal species, the so-called SM1 Euryarchaeon. To date, this archaeon resists cultivation attempts, but it can be harvested *in situ* in high purity: The microorganisms form mono-species biofilms, which attach to poly-ethylene nets provided in the spring-outflow. This attachment process is mainly driven by extraordinary, filamentous cell-surface appendages. These so-called hami[1] exhibit a unique architecture: The main filament is barbed-wirelike, at the distal end it carries a nano-scaled hook. Three filaments twisted around each other form a 7nm thin hamus thread with so-called prickles sticking out in regular intervals and finally wind up to a grappling hook. The biofilm formation resembles stromatolites- the oldest trace of life- which played an important part in development of life in this Earth. The anoxic and probably autotrophic life-style of the SM1 Euryarchaeon may present an old window into genesis of life on Earth and even on Mars.

[1]Moissl et al. (2005): The unique structure of archaeal “hami”, highly complex cell appendages with nanograppling hooks. Mol Microbiol 56(2): 361-70.

THE RELEVANCE OF BIOSIGNATURES IN SIDERITE-NODULES: AN EXAMPLE FROM QUATERNARY CONTINENTAL DEPOSITS (TIBERINO BASIN, ITALY)

Gallo G.[1], Baldanza A.[1], Bizzarri R.[1], Cavalazzi B.[2], Comodi P.[1], Frondini F.[1], Rigo M.[3],

[1]*Università degli Studi di Perugia, Italy*
[2]*Università di Bologna, Italy*
[3]*Università degli Studi di Padova, Italy*

Microbial-induced formation of siderite as well as the development of Fe-rich nodules are fields of active research in biomineralization and economic geology. They also feed new frontiers in the astrobiological research. The siderite and Fe-oxides formation could result from microbial mineralization of organic matter or from bacterial Fe(III) reduction. Microbiological studies also suggest that Fe-rich nodules are at least partially biogenic. However, morphological biosignatures have rarely been reported from this peculiar microhabitat.

Here, we report unique, well preserved microfossils recovered in Fe-rich nodules microhabitat. Dark brownish, heavy disk-shaped Fe-rich nodules were detected as isolated bodies, forming horizons within the Plio-Pleistocene Dunarobba clays deposited in a deep lacustrine environment of the Tiberino Basin, Italy. These nodules, dominated by Fe-carbonates (siderite) and -oxides (hematite), contain translucent, non-septate, isolated and large filamentous microfossils (average diameter 20 µm). Their morphology resulted very similar to some Fe-oxidizing sheathed bacteria. Moreover, the depleted $\delta^{13}C$ values (as negative as −26.05‰ VPDB) from siderite strongly support the role of microbes in its formation. Fossil Fe-microbes were only observed within the siderite-nodules (and not from the host-sediments), suggesting that they were not just endoliths or hitchhikers from the surrounding environment. The role of these microfossils in the nodules formation can, therefore, be discussed.

Introducing the potential of antimicrobial materials for human spaceflight activities

C. Hahn[1, 3] , M. Hans[2], F. Mücklich[2], R. Moeller[1], G. Reitz[1], R. Wirth[3], P. Rettberg[1]

[1] Department of Radiation Biology, Institute of Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany
[2] Department of Material Science & Engineering, Saarland University, Saarbrücken, Germany
[3] Institute for Microbiology and Archaea Center, Faculty of Biology and Preclinical Medicine Natural Science III, University of Regensburg, Regensburg, Germany

Corresponding Author: Claudia.Hahn@dlr.de

Claudia1.Hahn@biologie.uni-regensburg.de

Journeys to special destinations of astrobiological interests require long-term residence of astronauts in confined stations and habitats. The microbial contamination in confined habitats is diverse. Maintaining astronauts' health during these journeys is of prime importance for the success of any mission. Different sterilization procedures exist, but for various reasons not adequate for space missions. The use of antimicrobial surfaces is a promising tool to reduce microbial contaminations. Antimicrobials are characterized by their relative short reaction time, long efficiency, broad application, and avoidance of microbial resistance. To examine the benefit of antimicrobial surfaces for astronauts' and spacecraft hardware, systematic studies with selected indicator species, e.g. *Escherichia coli* or *Staphylococcus* sp., were conducted. In contrast to an exposure on stainless steel, microorganisms exposed on copper died within a few hours. The experimental results are very promising to other areas, e.g., clinical application. Here, we would like to present the data and ideas on the future utilization of antimicrobial surfaces in human explorative missions.

Chair: Frances Westall
Co-chair: Zita Martins

Evidence for silica springs at the surface of Mars from the Nakhla meteorite

M. R. Lee[1], I. MacLaren[2], A. Kovacs[3], T. Tomkinson[1], V. R. Phoenix[1].

[1]School of Geographical & Earth Sciences, University of Glasgow, G12 8QQ, U.K. Martin.Lee@Glasgow.ac.uk. [2]School of Physics & Astronomy, University of Glasgow, G12 8QQ, U.K. [3]Ernst Ruska-Centrum für Mikroskopie und Spektroskopie mit Elektronen, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany.

Hydrothermal springs are sites where warm and nutrient-rich water meets a planetary surface, and are ideal environments for microbial colonisation. These springs are also important to astrobiology because rapid mineralization as the hot water cools facilitates the preservation of biosignatures. Good evidence has been found for silica springs at the surface of Mars and in association with Hesperian volcanic landforms [1]. The martian meteorite Nakhla also provides tantalising evidence that silica springs may have been active much more recently in the planet's history. Olivine crystals in Nakhla contain veins of a hydrous Mg-Fe silicate that formed at ~633 Ma [2]. Analytical scanning transmission electron microscopy shows that the Mg-Fe silicate is principally composed of ~3-5 nm particles of silica, each of which has a thin coating of ferrihydrite and smectite. The most likely origin for these nanoparticles is very rapid cooling and oxidation of hydrothermal solutions as they approached the surface of Mars, and so we conclude that the Nakhla meteorite preserves the plumbing system of an Amazonian hot spring.

[1] Skok et al. (2010) *Nature Geoscience* **3**, 838-841. [2] Borg and Drake (2005) *Journal of Geophysical Research* **110**, E12S03.

Possible association of ferrous phosphates and ferric sulfates in hydrothermal deposits in Gusev Crater, Mars

Christian Schröder[1], Jiefei Mao[2], Elisabeth M. Hausrath[3], Richard V. Morris[4], Steve W. Squyres[5], Stefan B. Haderlein[6]

[1]Biological and Environmental Sciences, School of Natural Sciences, University of Stirling, Stirling FK9 4LA, Scotland, UK, christian.schroeder@stir.ac.uk; [2]Copernicus Institute-Environmental Sciences and Department of Earth Sciences – Geochemistry, Faculty of Geosciences, Utrecht University, The Netherlands; [3]Department of Geoscience, University of Nevada, Las Vegas, USA. [4]Astromaterials Research and Exploration Science, NASA Johnson Space Center, Houston, USA; [5]Department of Astronomy, Cornell University, Ithaca, USA; [6]Center for Applied Geoscience, Eberhard Karls University, Tübingen, Germany.

Light-toned soil deposits were excavated at Paso Robles by Mars Exploration Rover Spirit's wheels during its ascent of Husband Hill in Gusev Crater. They are rich in sulfur and ferric sulfate, share a high abundance of phosphorous with surrounding rocks, and were probably formed by hydrothermal processes. Up to 10 % phosphate mineral phases are present in Paso Robles soils but the phosphate mineralogy is ill-constrained. Calcium phosphates could not be confirmed by visible/near-infrared or thermal emission data. Instead, evidence for ferric phosphates has been put forward. Ferrous phosphates were initially ruled out because ferrous phases in Mössbauer spectra obtained from two light-toned soil deposits at the Paso Robles location had been assigned to silicates, assuming physical mixing of the light-toned materials and the overlying basaltic sand. We present an alternative interpretation, which includes ferrous or mixed-valence phosphates such as vivianite or other members of the homologous series $Fe^{2+}_3(PO_4)_2 \cdot n(H_2O)$. We present evidence from Spirit's instruments for the possible co-existence of ferrous phosphates and ferric sulfates. We verified experimentally a reasonable scenario for the formation of ferrous phosphates and ferric sulfates under hydrothermal conditions. The determination of sulfur and phosphorous minerals and associated iron oxidation states provides important constraints on the environmental conditions at the time of deposition. If our interpretation is correct, the experimental results would speak against oxidative acid-sulfate alteration, and for more moderate pH and less oxidizing conditions. Sulfur, phosphorous, and iron are key nutrients of astrobiological importance, and their mineralogy controls the bioavailability of these elements.

ALH84001 carbonates formed by low temperature replacement of plagioclase glass

A. Macartney[1], T.Tomkinson[1], E. R. D. Scott[2]. M. R. Lee[1]

[1] *School of Geographical and Earth Sciences, University of Glasgow, UK.*
E-mail: a.macartney.1@research.gla.ac.uk
[2] *Hawai'i Institute of Geophysics and Planetology, USA.*

The meteorite ALH84001 has been suggested to contain evidence for Martian bacteria [1]. These structures were found within secondary carbonates that can be divided into three types: Mg-Fe-Ca zoned discs, carbonate globules within glass and irregular carbonates in crush zones [2]. We have sought to test three models for carbonate formation: (i) glass and orthopyroxene replacement [3, 4]; (ii) pore space cementation [5] (iii) shock melt solidification [2]. Options i and iii preclude biosignatures.

Using thin section ALH84001-173, SEM X-ray element maps located carbonate-glass interfaces. A FEI DuoMill focused ion beam (FIB) cut electron-transparent foils across glass-carbonate interfaces for imaging and electron diffraction work using a FEI T20 TEM. SEM imaging and elemental mapping revealed carbonates in fractures and distinct clusters of carbonate-glass patches spanning 0.1-0.2mm; the fine scale intergrowth observed is consistent with carbonates replacing glass.

References: [1] McKay. D. and Gibson Jr. E. 1996. *Science* 273:924 [2] Scott. E. R. D. *et al*. 1997. *Nature*, 387: 377–379 [3] Treiman, A. 1995. *Meteoritics*, 30:294 –302. [4] Gleason. J. *et al*. 1997. *Geochimica et Cosmochimica Acta* 61:3503–3512. [5] Halevy. I. *et al*. 2011. *PNAS*, 108: 16895–16899

Acknowledgements: Dr Kevin Righter/NASA-JSC (sample loan).

Organic matter in martian meteorites: ingredients for life or contamination?

Dominic Papineau

London Centre for Nanotechnology, Department of Earth Sciences, University College London, London, UK.

Organic matter has been reported as both indigenous and contaminant in Martian meteorites. Contamination is post-Mars ejecta and most likely from Earth. Crystallinity mapped by spectral imaging, molecular fragment analysis, heteroatom composition, and isotopically heavy carbon isotope compositions have all been used to argue for some indigenous organic matter in martian meteorites. This is not unexpected given that terrestrial peridotites and mafic rocks often contain traces of organic matter. Such type of organic matter could have played a role in prebiotic chemistry. Nanofilms of disordered carbon have been recently discovered in the Chassigny and ALH84001 meteorites.

In a thin section of the Chassigny dunite, organic matter is often associated with apatite-magnetite inclusions in maskelynite spheroidal grains, in the fayalite-dominated matrix. Contamination by epoxy from the mounting polymer occurs throughout the thin section, including near the areas where distinct ‘kerogen-like’ organic matter occurs. In ALH84001 orthopyroxenite, organic matter occurs in association with carbonate-magnetite rosettes. Different crystallinities of the organic matter can be seen within a single thin section of ALH84001, which might imply an indigenous origin. However, Raman spectra of organic matter associated with epoxy in cracks of the ALH84001 thin section demonstrate it is kerogen-like, and that it also traps shrapnel, likely from the cutting saw. Clearly, techniques to cleanly prepare precious small quantities of samples need to be developed before Mars Sample Return.

General Talk *17:30-18:00*

Chair: Frances Westall

On the geology of Edinburgh and its surroundings: death of an ocean, volcanoes, trilobite eyes and the optics of Descartes and Huygens…and more

Euan Clarkson, *University of Edinburgh*

Wednesday 15th October

Instrumentation for geochemical and biological exploration *09:00-12:00*

Session supported by STFC Geological Repositories Network (GeoRepNet)

Chair: Muriel Gargaud
Co-chair: John Parnell

Raman Measurements under Simulated Martian conditions

Bettina Haezeleer[1]*, Ute Böttger[2], Heinz-Wilhelm Hübers[2], Jean-Pierre deVera[2], Stefan Fox[1], Henry Strasdeit[1]

[1] Department of Bioinorganic Chemistry, Institute of Chemistry, University of Hohenheim, 70599 Stuttgart, Germany, [2] DLR Institute of Planetary Research, 12489 Berlin, Germany

* E-mail: Bettina.Haezeleer@uni-hohenheim.de

Raman spectroscopy is generally regarded as nondestructive. It is easy to apply, as no extensive sample preparation is necessary. As part of the ExoMars mission 2018, a compact Raman laser spectrometer (RLS) will analyze the mineral composition of the Martian soil and in particular search for organic matter [1]. Considering the possibility that life once evolved on Mars, its chemical traces may be detectable in Martian mineral matrices [2].

Our investigations on biomolecules have shown that high laser powers can influence the spectral outcome and even lead to complete sample destruction. To ascertain parameters and sample preparations favorable for an application on Mars, we developed a new measuring set-up simulating Martian environmental factors. Using a cryostat as simulation chamber, the samples were cooled down stepwise to 200 K. To minimize the oxygen level, a special pump created a stable vacuum of ca. 10^{-6} mbar. Different sample types (powders, pellets) have been measured with increasing laser power. The results are quite revealing as they show a major influence of the physical properties of the samples.

[1] F. Rull et al., 42nd Lunar and Planetary Science Conference, LPI Contribution No. 1608, Abstract No. 2400 (2011).
[2] F. Westall et al., *Planet Space Sci.* 59: 1093–1106 (2011).

Preparations for the use of Raman spectrometers on Mars

C. Malherbe [1], R. Ingley [1], I. B. Hutchinson [1], A. S. Carr [2], A. Boom [2], H.G.M. Edwards [1]

[1]Department of Physics and Astronomy, Space Research Centre, University of Leicester, Leicester LE1 7RH, United Kingdom .[2]Department of Geography, University of Leicester, Leicester LE1 7RH, United Kingdom.

Raman spectroscopy has been selected as a non-destructive powerful analytical method for forthcoming planetary exploration. In the context of the upcoming ExoMars and NASA 2020 missions (developed by the European Space Agency, IKI Roscomos and NASA) analysis of the biological and geological terrestrial analogues using laboratory instrumentation is of great importance; especially testing the performance of flight-like operating modes and conditions on the feasibility of flight instruments meeting their science goals. Here we present a set of measurements of terrestrial analogues (among them desert varnishes) selected in preparation for in-situ Raman analysis on Mars. Laboratory instrumentation has been used to fully characterise the samples in addition to being operated in modes consistent with ExoMars RLS instrument flight designs, sample preparation and delivery. We discuss the performance of the spectrometers regarding the detection of the target signatures and their geological context. The impact of instrument operating modes and application of flight instrument sampling philosophy (i.e. spot size, grain size, number of target locations, sample preparation and delivery) on the signal intensity and the limits of detection are also discussed.

Sulfate minerals: A problem for the detection of organic compounds on Mars?

James M.T. Lewis[1]*, Jonathan S. Watson[1], Jens Najorka[2] and Mark A. Sephton[1].

[1] *Imperial College London, Earth Science & Engineering, London, SW7 2AZ, UK*
**james.lewis07@imperial.ac.uk*
[2]*Natural History Museum, Imaging and Analysis Centre, London, SW7 5BD, UK*

Identifying organic molecules in situ on Mars would greatly improve our understanding of the planet and its potential to have hosted life. However, organic detection missions have so far presented no conclusive evidence for the existence of organic compounds in Martian soils. A possible cause is the confounding influence of Martian mineralogy on lander and rover pyrolysis experiments. In particular, minerals that break down to give oxygen at standard pyrolysis temperatures, such as chlorine salts (perchlorates) and certain sulfate species. While the negative influence of perchlorates on pyrolysis experiments is relatively well understood there has been little investigation of the effects sulfates may have on thermal extraction techniques on Mars.

Natural samples containing jarosite, an iron sulfate, and lignite were collected from Dorset, UK and analysed using pyrolysis-GC-MS. From 500 °C peaks for sulfur dioxide and carbon dioxide were observed but oxygen and organic compounds were not detected. Jarosite was synthesised and during pyrolysis released sulfur dioxide and oxygen at a 2:1 ratio, consistent with the decomposition of sulfate ions. In the natural samples the missing oxygen was consumed in the destruction of organic matter. Along with perchlorates, jarosite represents a significant complication in the operation of pyrolysis units on Mars.

Biosignatures of methanogenic archaea by Confocal Raman Microspectroscopy (CRM)

Paloma Serrano[1, 2], Antje Hermelink[3], Peter Lasch[3], Jean-Pierre de Vera[4], Ute Böttger[4], Dirk Wagner[2].

[1]Alfred Wegener Institute Helmholz Centre for Polar and Marine Research, Potsdam, Germany. [2] GFZ German Research Centre for Geosciences, Potsdam, Germany. [3] Robert Koch Institute, Berlin, Germany. [4] German Aerospace Center (DLR), Berlin, Germany.

Methanogenic archaea are anaerobic chemotrophic microorganisms that meet many of the metabolic and physiological requirements for survival on the martian subsurface. In particular, methanogens from Siberian permafrost are extremely resistant against different types of environmental stresses as well as simulated martian thermo-physical and subsurface conditions, making them promising model organisms for potential life on Mars. Raman spectroscopy is a vibrational spectroscopic technique that has shown a remarkable potential in microbial identification. It provides fingerprint-like information about the overall chemical composition of the samples and allows a nondestructive investigation. The biosignatures of *Methanosarcina soligelidi* SMA-21 were characterized by CRM during the growth phases at a single-cell level, which presented a high heterogeneity and diversity in the chemical composition of the cells and detectible subpopulation differences. This study also highlighted potential technical challenges concerning the Raman detection of methanogenic archaea (and other non-pigmented microorganisms) embedded on a mineral substrate. The biosignatures of permafrost and non-permafrost strains in the stationary phase of growth were also characterized by CRM. A cluster analysis of the spectra revealed that permafrost and non-permafrost strains have a different overall chemical composition, which has possible evolutionary implications.

Searching for signs of life with the NOMAD spectrometer suite on the ExoMars Trace Gas Orbiter.

M.R. Patel[1,2], A.C. Vandaele[3], J.-J. López-Moreno[4], G. Bellucci[5], F. Daerden[3] and the NOMAD team

[1]*Department of Physical Sciences, The Open University, Milton Keynes, UK*
[2]*Space Science and Technology Department, STFC Rutherford Appleton Laboratory, Didcot, Oxfordshire, UK*
[3]*Belgian Inst. for Space Aeronomy, Planetary Aeronomy, Bruxelles, Belgium,*
[4]*Instituto de Astrofisica de Andalucia IAA-CSIC, Granada, Spain,*
[5]*Instituto di Astrofisica e Planetologia Spaziali, Roma, Italy*

email: manish.patel@open.ac.uk

Introduction:

NOMAD, the "Nadir and Occultation for MArs Discovery" spectrometer suite is a key instrument in the payload for the ExoMars Trace Gas Orbiter mission 2016. This instrument suite will conduct a spectroscopic survey of Mars' atmosphere in the UV, visible and IR regions covering the 0.2-0.65 and 2.2-4.3 μm spectral ranges, searching for and mapping atmospheric gases relevant to astrobiology. NOMAD's observation modes include solar occultation, nadir and limb observations. Its spectral resolution surpasses previous surveys in the UV and infrared by more than one order of magnitude.

NOMAD will search for trace gases in the martian atmosphere, potentially produced as the by-product of geological processes and/or life. NOMAD will identify potential source regions of trace gas species and provide crucial information on the nature and evolution of the processes involved. NOMAD will also extend the survey of the major climatologic cycles of Mars such as the water, carbon and ozone cycles, and provide information on their different components, including isotopic fractionation and atmospheric escape processes.

Spatial heterogeneity of biomarkers in analogue environments

Adam H. Stevens*, Elena S. Amador [1], Morgan L. Cable [2], Nosheen Chaudry [3], Thomas Cullen [3], Diana Gentry [4], Malene B. Jacobsen [5], Gayathri Murusekan [6], Edward W. Schwieterman[1], Amanda Stockton [2], Chang Yin [7], David C. Cullen [3] and Wolf Geppert [7]

**The Open University, UK*
[1]*University of Washington, USA*
[2]*NASA Jet Propulsion Laboratory, California Institute of Technology, USA*
[3]*Cranfield University, UK*
[4]*Stanford University, USA*
[5]*University of Copenhagen, Denmark*
[6]*University of Turku, Finland*
[7]*Stockholm University, Sweden*

Understanding the spatiotemporal distribution of biomarkers is important for planning extra-terrestrial life detection strategies. In a typical planetary exploration scenario a sampling location must be chosen using remote sensing data, and if a difference of a few tens of meters or centimeters makes a large difference to the results of analyses, science objectives may not be met.

We conducted a planetary exploration analogue expedition to test the robustness of three common biomarker detection methods to measure the spatial heterogeneity of biomarkers across sample sites. Sampling sites across recent Icelandic lava fields (Fimmvörđuháls and Eldfell) spanned four nested spatial scales from: 1 m to >1 km.

Visible cell counts, ATP assay and qPCR all displayed spatial variation at certain scales. Distance had no significant effect on variability in cell counts and qPCR data, but was positively correlated with ATP variability. No correlation between cell counts and either ATP or qPCR results was significant at any scale; ATP quantification and the archaeal and fungal qPCR data showed a marginal negative correlation at the 1 m level.

These results highlight the difficulty of choosing a 'good' biomarker: different methods not agree with each other, but may also be differentially representative of the overall area. We intend to expand on this work by conducting a follow-up sampling campaign with more detailed assays of physicochemical site properties to characterize the relationship between different scales of site property diversity and biomarker diversity in light of these results.

A hyperspectral Imager for Astrobiology

Matt Gunn[1], Rachel Cross[1], Claire R. Cousins[2], Dave Langstaff[1], Andrew Evans[1], Laurence Tyler[1], Mark Fox-Powell[2], Charles Cockell[2]

1. Aberystwyth University
2. University of Edinburgh

Multispectral camera systems have been widely used for the in situ characterisation of environments on the Martian surface. Recent developments in hyperspectral imaging technology could significantly enhance the capabilities of spectral imaging systems on future planetary landers. High resolution imaging in combination with continuously variable spectral discrimination and Ultra Violet light excitation will allow the remote detection of organic molecules via fluorescence spectroscopy in addition to the mapping of environments via conventional hyperspectral imaging techniques. The working principle and potential capabilities of such a hyperspectral camera will be discussed and preliminary results from the field test of a prototype instrument in Iceland will be presented.

Chair: Rocco Mancinelli
Co-chair: Daniela Billi

Biofilms in space - the experiment BOSS on the EXPOSE R-2 mission

Petra Rettberg and the BOSS team*

[1]*DLR, D, petra.rettberg@dlr.de*

Microorganisms organized into multilayered biofilms embedded within self-developed extrapolymeric substances (EPS matrix) are among the oldest clear signs of life on Earth and might also be the first forms of life to be detected on other planets in our solar system. In the space experiment BOSS the hypothesis will be tested that biofim-forming microorganisms are more resistant to the environmental conditions as they exist in space and on Mars compared to the same bacteria from planctonic cultures. Test parameter will be survival after exposure to space vacuum and simulated martian atmosphere and pressure alone and in combination with extraterrestrial and mars-like solar UV radiation. Micoorganisms growing as biofilm or planctonically investigated in BOSS are (i) *Deinococcus geothermalis,* (ii) spores of *Bacillus horneckiae*, (ii) *Chroococcidiopsis* sp., (iii) *Halococcus morrhuae* within a biofilm of *Halomonas muralis* and *(iv) Gloeocapsa* sp., previously isolated from a natural community using outer space as the selection method. Analysis of survival and metabolic activity will be performed by culture-dependent and culture-independent methods, e.g. determination of cfu, MPN, ATP, FISH, LiveDead staining. The results of this experiment will contribute to our understanding of life in extreme environments on Earth and on other planets with emphasis on adaption to desiccation and UV radiation. The direct comparison of the survival strategies of different microbial species living in biofilms or as planctonic cells will also give new insights into the adequacy of actual planetary protection measures and may support the development of new life detection technologies for space application.

***BOSS team**: Petra Rettberg, Simon Barczyk, Elke Rabbow and Stefan Leuko (DLR, D); Daniela Billi (Università di Roma, IT); Charles Cockell (University of Edinburgh, UK); Jan Frösler, Jost Wingender, Hans-Curt Flemming (Universität Duisburg-Essen); Corinna Panitz (RWTH Aachen, D); Helga Stan-Lotter (University of Salzburg, AT); Kasthuri Venkateswaran (Jet Propulsion Laboratory, USA)

BIOMEX: Three different steps to approach a systematic determination of habitats and stable biosignatures in space- and Mars-like environments

Jean-Pierre de Vera[1] and BIOMEX-team[2]

[1]German Aerospace Center (DLR), Institute of Planetary Research, 12489 Berlin, Germany
[2]BIOMEX-team: Ute Böttger[1], Andreas Lorek[1], David Wolter[1], Heinz-Wilhelm Hübers[1], Rosa de la Torre Noetzel, Francisco J. Sánchez (INTA, Madrid, Spain), Daniela Billi, Mickael Baqué, Cyprien Verseux (Uni Tor Vergata, Rome, Italy), Petra Rettberg, Elke Rabbow, Corinna Panitz, Günther Reitz, Thomas Berger, Ralf Möller, Maria Bohmeier, Stefan Leuko, Gerda Horneck (German Aerospace Center, Cologne, Germany), Frances Westall (University of Orléans, France), Jochen Jänchen (TH Wildau, Germany), Jörg Fritz (Museum für Naturkunde, Berlin, Germany), Cornelia Meyer (Horizontereignis gUG, Berlin, Germany), Silvano Onofri, Laura Selbmann, Laura Zucconi, Claudia Pacelli (University della Tuscia, Viterbo, Italy), Natalia Kozyrovska (IMBG, Natl. Acad. Sci., Kyiv, Ukraine), Thomas Leya (Fraunhofer IZI-BB, Potsdam, Germany), Bernard Foing (ESA/ESTEC, Noordwijk, Netherlands), René Demets (HE Space for ESA, Noordwijk, Netherlands), Charles S. Cockell, Casey Bryce (University of Edinburgh, UK), Karen Olsson-Francis (Open University, Milton-Keynes, UK), Dirk Wagner, Paloma Serrano (GFZ Potsdam, Germany), Howell G.M. Edwards (University of Bradford, UK), Jasmin Joshi, Björn Huwe (University of Potsdam, Germany), Ueli Grossniklaus, Moritz Rövekamp (University of Zürich), Pascale Ehrenfreund, Andreas Elsaesser (Leiden University, Leiden, Netherlands), Dirk Schulze-Makuch, Nina Feyh, Ulrich Szewzyk (TU Berlin, Germany), Sieglinde Ott, Joachim Meessen (Heinrich-Heine-University, Institute of Botany, Düsseldorf, Germany).

BIOMEX (Biology and Mars Experiment) is a space experiment on the exposure platform EXPOSE-R2 launched by the Progress 56 mission on 24 July and placed on the outer side of the Russian Zvezda Module of the International Space Station (ISS). Twenty-five international institutes are working together and sharing different methods, planetary simulation facilities, and logistics to obtain information about the vitality of the tested microorganisms and the stability of biomolecules as possible biosignatures. This experiment comprises three investigational steps from the field to space: (i) field work with sample collection and habitat characterization at field sites with or without Mars analogy, (ii) Mars simulation experiments in the lab and (iii) exposure to real space conditions. For the second and third steps some of the microorganisms and bio-molecules are embedded in Mars-analog regolith mixtures, placed in compartments enriched with Mars-like CO_2 -atmosphere and exposed to solar irradiation levels approaching those affecting the surface of Mars to test habitability on Mars, as well as the ability to detect the selected, Mars-exposed bio-molecules. One of the aims of this experiment is to investigate the specific bio-related spectra of resistant molecules obtained by fluorescence analysis, Raman-spectroscopy, IR- and UV/VIS spectrometry before and after simulated and real space exposure. The obtained database of stable bio-molecules will support future exploration missions to Mars whose main goal is the search for life.

Lichens survived ground simulation tests before integration on board of the EXPOSE R2 mission

R. de la Torre Noetzel[1], Mª L. Martín Cerezo[1], E. Rabbow[2], G Horneck[2], J. Meeβen[3]

S. Ott[3], L.Gª Sancho[4], J. P. de Vera[5]

[1]INTA, Spanish Aerospace Research Establishment, Madrid, Spain
[2]DLR,German Aerospace Center, Cologne, Germany
[3]HHU, Heinrich-Heine University Düsseldorf, Germany
[4]UCM, Univ. Complutense Madrid, Madrid, Spain
[5]DLR,German Aerospace Center, Berlin, Germany

R. de la Torre Noetzel, e-mail: torrenr@inta.es, tel: +0034915291589, fax +0034915291633

Ground simulation tests are necessary for selection of the most promising biological organisms for flight experiments in Low Earth Orbit or other space destinations: Simulation of the environmental parameters of the mission, as well as of sample assembly and disassembly, need to be performed, allowing the qualification of the experiment and facilitating the post-flight analysis of the exposed biological material and thus, a deeper understanding of the individual and synergistic effects of space.

This work is a presentation of the results obtained with the lichen species *Circinaria gyrosa*, after the Experiment Verification tests (EVT) and Space Verification tests (SVT) in the frame of the EXPOSE-R2 Mission Preflight Test Program, performed at DLR (Cologne, Germany), as part of the EXPOSE-R2 Mission Preflight Test Program. The high vitality and resistance capacity of *C. gyrosa*, demonstrated with the PSII values measured after reactivation in the laboratory and the CLSM (Confocal Laser Scanning Microscopy) results confirm the high survival potential of these species to space and Mars conditions, taking part of the BIOMEX experiment (Biology and Mars Experiment, EXPOSE R-2, ISS, 2016-2018) and contributing to our understanding of extremotolerance and the Lithopanspermia hypothesis.

Different stress responses of *Deinococcus geothermalis* exposed as biofilms or planktonic cells

C. Panitz[1, 2)], P. Rettberg (PI) [2)], E. Rabbow[2)], J. Frösler[3)], J. Wingender[3)], H.-C. Flemming[3)], G. Reitz[2)]

1) *Uniklinikum/RWTH Aachen, Institute of Pharmacology and Toxicology, 52074 Aachen, Germany*
2) *DLR, Institute of Aerospace Medicine, Radiation Biology Department, 51170 Cologne, Germany*
3) *University of Duisburg-Essen, Faculty of Chemistry, Biofilm Centre, 45141 Essen, Germany*

In addition to the several extreme environments on Earth, Space can be considered as just another exceptional environment with a unique mixture of stress factors. The question is whether there are different strategies for individually living microorganisms (planktonic state) compared to a microbial consortium of the same cells (biofilm state) to cope with the stress. Answers to this are expected from the scientific outcom of the space experiment BOSS (Biofilm organisms surfing Space) with participation of *Deinococcus geothermalis*. In several preparatory tests survival as consequence of the organization form was investigated after desiccation, temperature extremes and fluctuations, simulated extraterrestrial and Mars-like UV radiation, vacuum and simulated Martian atmosphere tested individually or in combination at the Planetary and Space Simulation facilities of the German Aerospace Center in Cologne. The results demonstrate that *D. geothermalis* remains viable in the desiccated state over weeks to months, whereas culturability was preserved in biofilm cells at a significantly higher level than in planktonic cells. Furthermore, cells of both sample types were able to survive simulated space and Martian conditions and showed high resistance towards irradiation with monochromatic and polychromatic UV light. The findings will contribute to the understanding of the opportunities and limitations of life under the extreme environmental conditions of space or other planets as function of the state of life.

Tanpopo: Astrobiological exposure and capture experiments of microbes and micrometeorite

Yuko Kawaguchi[1], Eiichi Imai[2], Hirofumi Hashimoto[1], Kyoko Okudaira[3], Satoshi Sasaki[4], Hideyuki Kawai[5], Makoto Tabata[5], Shin-ichi Yokobori[6], Issay Narumi[7], Kazumichi Nakagawa[8], Kaori Tomita-Yokotani[9], Nobuhiro Hayashi[10], Hajime Mita [11], Kensei Kobayashi[12], Yoko Kebukawa[12], Hikaru Yabuta[13], Masumi Higashide[1], Hajime Yano[1], Akihiko Yamagishi[6] and Tanpopo WG.

[1]Institut of Space and Astronomical Science/Japan Aerospace Exploration Agency (ISAS/JAXA), [2]Nagaoka Univ., of Technol., [3]Univ., Aizu, [4]Tokyo Univ., Technol., [5]Chiba Univ., [6]Tokyo Univ., Pharm., Life Sci., [7]Toyo Univ., [8]Kobe Univ., [9]Tukuba Univ., [10]Tokyo Insti., Technol., [11]Fukuoka Inst., of Technol., [12]Yokohama Natl., Univ., [13]Osaka Univ.,

To investigate the panspermia hypothesis and the chemical evolution, we are proposing an astrobiological space experiment at the orbit of Japan Experimental Module (JEM) of ISS. The mission is called Tanpopo. We are planning to capture micro-particles with microbes, micrometeorites and space debris by using a silica aerogel. Capture panels with silica aerogels will be exposed at JEM of ISS to collect impacted particles for a year. We also test the survivability of some microbes and organic compounds under the space environment. After transporting the Capture panels with silica aerogels and Exposure panels with microbes and organic compounds to the ISS, theses will be attached to the Exposed Experiment Handrail Attachment Mechanism (ExHAM) at the exposed facility (EF) of ISS. We are going to introduce the detail of these flight models and the current status of the Tanpopo mission.

Preservation of cyanobacterial biomarkers after Martian ground-based simulation exposure

Mickael Baqué[1], Cyprien Verseux[1], Ute Böttger[2], Elke Rabbow[3], Daniela Billi[1] and Jean-Pierre Paul de Vera[2]

[1]*University of Rome Tor Vergata, Department of Biology, Rome, Italy*
[2]*German Aerospace Center (DLR), Institute of Planetary Research, Berlin, Germany*
[3]*German Aerospace Center (DLR), Institute of Aerospace Medicine, Radiation Biology Department, Köln, Germany*

The space mission EXPOSE-R2 successfully launched on the 24th of July 2014 to the International Space Station is carrying the BIOMEX (BIOlogy and Mars EXperiment) experiment aimed at investigating the endurance of extremophiles and stability of biomolecules. Among the selected extremophiles there are cyanobacteria of the genus *Chroococcidiopsis* well known for their relevance in astrobiology tasks dealing with the search for life on Mars and for future space applications. During the ground-based simulations, *Chroococcidiopsis* cells mixed with two Martian mineral analogues were exposed to high UV irradiation combined or without Martian simulated atmosphere. Survival and preservation of potential biomarkers such as photosynthetic, photoprotective pigments or DNA were assessed by colony forming ability, Confocal Laser Scanning Microscopy, Raman spectroscopy and PCR-based assays. DNA and photoprotective pigments (namely carotenoids) showed high preservation potentials and were detectable after simulations of the real space exposure mission (500MJ/m² of full UV 200-400nm irradiation and Martian simulated atmosphere). Data gathered during the ground-based simulations will contribute to interpret future results from space experiments and guide our search for life on Mars and other bodies of interest.

Chair: Kai Finster
Co-chair: Axel Brandenburg

Interior structure and possible habitability of ocean worlds

L. Noack(1), D. Höning(2), H. Lammer(3) and J.H. Bredehöft(4)

(1) Royal Observatory of Belgium
(2) German Aerospace Center
(3) Austrian Academy of Sciences Space Research Institute
(4) University of Bremen

In the last decade, the number of detected exoplanets has increased to over thousand confirmed planets and more as yet unconfirmed planet candidates. The scientific community mainly concentrates on terrestrial planets (up to 10 Earth masses) in the habitable zone, which describes the distance from the host star where liquid water can exist at the surface (Kasting et al., 1993).

Another target group of interest are ocean worlds, where a terrestrial-like body (i.e. with an iron core and a silicate mantle) is covered by a thick water-ice layer - similar to the icy moons of our solar system but with several Earth masses (e.g. Grasset et al., 2009; Kaltenegger et al., 2013).

When an exoplanet is detected and confirmed as a planet, typically the radius and the mass of it are known, leading to the mean density of the planet that gives hints to possible interior structures. A planet with a large relative iron core and a thick ocean on top of the silicate mantle for example would have the same average planet density as a planet with a more Earth-like appearance (where the main contributor to the mass is the silicate mantle).

In this study we investigate

1) how the radius and mass of a planet depend on the amount of water, silicates and iron present (after Wagner et al., 2011)

2) the temperature profile in an liquid ocean considering high-pressure and -temperature thermodynamic properties of water (IAPWS)

3) the occurence of high-pressure-ice in the water-ice layer (note: we only consider surface temperatures at which liquid water exists at the surface) depending on surface temperature and planet radius (for an Earth-like mantle and core composition)

4) if the ocean layer influences the initiation of plate tectonics or the existence of volcanoes at the ocean-mantle boundary

We assume that ocean worlds may be called habitable (Class III/IV habitats after Lammer et al., 2009) if they have a liquid ocean layer (and without the occurence of high-pressure ice anywhere in the water layer), plate tectonics (especially the occurence of subduction zones and continental formation) and active volcanism and hydrothermal vents. Oceans where an ice layer forms but where the lowermost layer above the ocean-mantle boundary is again liquid, are called restricted habitable (Noack et al., in review).

References:

- Kasting, J.F., Whitmire, D.P., and Reynolds, R.T. (1993). Habitable Zones around Main Sequence Stars. Icarus 101, 108-128.

- Grasset, O., Schneider, J., and Sotin, C. (2009). A study of the accuracy of mass-radius relationships for silicate-rich and ice-rich planets up to 100 Earth masses. The Astrophysical Journal 693, 722-733.

- IAPWS. International Association for the Properties of Water and Steam website, http://www.iapws.org.

- Kaltenegger, L., Sasselov, D., and Rugheimer, S. (2013). Water-planets in the habitable zone: atmospheric chemistry, observable features, and the case of Kepler-62e and -62f. The Astrophysical Journal Letters, 775:L47 (5pp).

- Lammer, H., Bredehöft, J.H., Coustenis, A., Khodachenko, M.L., Kaltenegger, L., Grasset, O., Prieur, D., Raulin, F., Ehrenfreund, P., Yamauchi, M., Wahlund, J.-E., Grießmeier, J.-M., Stangl, G., Cockell, C.S., Kulikov, Yu.N., Grenfell, J.L., and Rauer, H. (2009). What makes a planet habitable? Astron Astrophys Rev 17, 181-249.

- Noack, L., Höning, D., Lammer, H., and Bredehöft, J.H. (in review). Water worlds: how life-friendly is an ocean deeper than on Earth? Astronomy & Astrophysics Letters, in review.

- Wagner, F.W., Sohl, F., Hussmann, H., Grott, M., and Rauer, H. (2011). Interior structure models of solid exoplanets using material laws in the infinite pressure limit. Icarus 214, 366-376.

Overestimating Eta-Earth: The Importance of Photo-Evaporation

Eric Lopez, Royal Observatory, University of Edinburgh.

Life as we understand it likely requires a close to Earth-sized or smaller planet to survive. Sub-Neptune and larger planets must have large gaseous envelopes, which reach enormous temperatures and pressures inhospitable to life, in order to explain their sizes. This has lead to a massive effort to estimate Eta-Earth, the frequency of Earth-sized planets orbiting within the habitable zone. However, the current population of Earth-sized planets and planet candidates discovered by NASA's Kepler mission, is dominated by highly irradiated planets on orbits less than ~50 days. On such orbits planets are bombarded by high amounts of EUV and x-ray radiation, which can photo-evaporate away planets with gaseous envelopes. Using models of planet evolution and photo-evaporation we show that the known population of short-period planets has been significantly sculpted by evaporation. We further show that most of the current population of Earth-sized planets and planet candidates could in fact be the striped remnants of gas-rich sub-Neptunes. This in turn means that current efforts to extrapolate the short-period Earth-sized population out to the habitable zone, may significantly overestimate the frequency of Earth-size planets.

Surface Flux Patterns on Planets in Circumbinary Systems, and Potential for Photosynthesis

Duncan H. Forgan (1,2,3), Alexander Mead (1), Charles S. Cockell (2), John A. Raven (4)

1: Scottish Universities Physics Alliance (SUPA), Institute for Astronomy, University of Edinburgh, UK
2: UK Centre for Astrobiology, School of Physics and Astronomy, University of Edinburgh, UK
3: Scottish Universities Physics Alliance (SUPA), School of Physics and Astronomy, University of St Andrews, UK
4: Division of Plant Sciences, University of Dundee at TJHI, The James Hutton Institute, Invergowrie, Dundee, UK

Recently, the Kepler Space Telescope has detected several planets in orbit around a close binary star system. These so-called circumbinary planets will experience non-trivial spatial and temporal distributions of radiative flux on their surfaces, with features not seen in their single-star orbiting counterparts. Earthlike circumbinary planets inhabited by photosynthetic organisms will be forced to adapt to these unusual flux patterns.

I will present calculations of the flux received by putative Earthlike planets (as a function of surface latitude/longitude and time) orbiting the binary star systems Kepler-16 and Kepler-47, two star systems which already boast circumbinary exoplanet detections. The longitudinal and latitudinal distribution of flux is sensitive to the centre of mass motion of the binary, and the relative orbital phases of the binary and planet. Total eclipses of the secondary by the primary, as well as partial eclipses of the primary by the secondary add extra forcing terms to the system.

The patterns of darkness on the surface are equally unique. Beyond the planet's polar circles, the surface spends a significantly longer time in darkness than latitudes around the equator, due to the stars' motions delaying the first sunrise of spring (or hastening the last sunset of autumn). In the case of Kepler-47, we also find a weak longitudinal dependence for darkness, but this effect tends to average out if considered over many orbits.

I will consider and discuss the prospects and challenges for photosynthetic organisms, using terrestrial analogues as a guide.

Spectropolarimetry, Biosignatures, and the Search for Homochirality

W E Martin, J H Hough, E Hesse, T Gledhill

University of Hertfordshire

The Polarimetry Laboratory at the University of Hertfordshire has been engaged for several years in performing high-sensitivity Stokes spectropolarimetric measurements on biological and inorganic materials. We have looked at the characteristic spectral signature of chlorophyll in biomaterials and the possibility of remotely detecting circular polarisation scattering arising from the homochirality of this complex molecule. The goal of this work is the evaluation of techniques for the remote detection of scattered light containing the spectropolarimetric signatures of biological material. The assumption is that convergent evolution may produce similar molecules on Earth-like exoplanets . We present a summary of laboratory measurements on biological materials including new work on the cyanobacterium *Chroococcidiopsis* (commonly known as a blue-green algae) and extensions to earlier work on leaves and lichens. The measurement of Stokes scattering coefficients to a level of ±0.0001 across visible wavelengths is described. We find that the largest optical signatures from our *Chroococcidiopsis* samples can be described by relatively simple optical scattering with internal reflections and that there is evidence that scattering within most samples having a cellular structure can produce circular polarization signatures that are likely to mask those arising from chiral properties.

Thursday 16th October

Chair: Paula Lindgren
Co-chair: Andreas Elsaesser

Shock-synthesis of amino acids via the impact of comets

ZITA MARTINS[1*] and MARK C. PRICE[2]

[1]*ESE, Imperial College London, SW7 2AZ, UK.*
[2]*School of Physical Sciences, University of Kent, Canterbury, Kent, CT2 7NH, UK.*

Comets may have exogenously delivered prebiotic organic compounds to the early Earth 4.5 to 3.8 million years ago, just before life originated on our planet (Schidlowski 1988; Schopf 1993; Moorbath 2005). For example, several amino acid precursors have been detected in comets (Crovisier et al. 2009), and the simplest amino acid glycine was detected on comet 81P/Wild-2 (Elsila et al. 2009). In addition, the impact of comets onto rocky surfaces could have generated the synthesis of complex organic molecules through a process of shock synthesis (Chyba et al. 1990; Chyba and Sagan 1992; Anders 1989; Furukawa et al. 2009). A*b initio* molecular dynamics simulations show that shock waves passed into comets could theoretically yield amino acids (Goldman et al. 2010). Laboratory experiments were performed for the first time to determine whether amino acids could be shock synthesised by replicating a comet impact (Martins et al. 2013). Our results show that the impact-shock of a typical cometary ice mixture produces several α-amino acids, including racemic mixtures of alanine and norvaline (D/L≈1), and the non-protein amino acids α-aminoisobutyric acid and isovaline. Therefore, the impact of comets onto rocky surfaces may synthesise some of the building blocks of life, expanding the inventory of resources available by the first living organisms on Earth and possibly elsewhere in our solar system.

Formation of Amino Acid Precursors and Nucleic Acid Bases from Simulated Interstellar Media and Their Robustness

Kensei Kobayashi[1, 2], Hayato Tokimura[1], Tomoyuki Matsuda[1], Yoko Kebukawa[1], Yumiko Obayashi[1], Takeo Kaneko[1], Yoko Kebukawa[12], Hajime Mita[3], Satoshi Yoshida[4], Hitoshi Fukuda[5], Yoshiyuki Oguri[5], Hirofumi Hashimoto[6], Shin-ichi Yokobori[7], Akihiko Yamagishi[2,6,7] and Tanpopo WG[6]

[1]Yokohama National University, [2]National Institutes of Natural Sciences, [3]Fukuoka Institute of Technology, [4]National Institute of Radiological Sciences, [5]Tokyo Institute of Technology, [6]Institute of Space and Astronomical Science/JAXA, [7]Tokyo University of Pharmacy and Life Science

A wide variety of organic compounds have been detected in extraterrestrial bodies such as meteorites, but there have a number of hypotheses to explain their origins. It was suggested that organic compounds were originally formed in ice mantles of interstellar grains in dense clouds. We irradiated a mixture of water, ammonia, carbon monoxide and/or methanol, major constituents of the ice mantles, with high-energy particles. Complex amino acid precursors with high molecular weights were detected in the products in high yields. Five nucleiobases were also identified in the proton irradiation products from a mixture of carbon monoxide, ammonia and water. Amino acid precursors and nucleic acid bases were much more stable than free amino acids against heavy ion- and UV-irradiation and heat. Thus it can be said that amino acid precursors and nucleic acid bases delivered from space were robust molecules for further chemical evolution in the primitive ocean. We will collect cosmic dusts, plausible carriers of extraterrestrial organics, in space in the Tanpopo Mission to support the scenario.

Exposure and Capturer of Amino Acids and their Precursors on the Japanese Experiment Module of the International Space Station

Mita Hajime[1], Kobayashi Kensei[2], Nakagawa Kazumichi[3], Yabuta Hikaru[4], Imai Eiichi[5], Kawaguchi Yuko[6], Hashimoto Hirofumi[7], Kanda Kazuhiro[8], Yoshida Satoshi[9], Kebukawa Yoko[2], Yokobori Shinichi[6], Yano Hajime[7], Okudaira Kyoko[10], Tabata Makoto[11], Kawai Hideyuki[11], Yamagishi Akihiko[6], and Tanpopo Working group[7]

[1]Fukuoka Institute of Technology, [2]Yokohama National University, [3]Kobe University, [4]OsakaUniversity, [5]Nagaoka University of Technology, [6]Tokyo University of Pharmacy and Life Science, [7]JAXA/ Institute of Space and Astronautical Science, [8]University of Hyogo, [9]Natinal Institute of Radiological Sciences, [10]University of Aizu, [11]Chiba University

A Japanese astrobiological experiment called TANPOPO mission will be conducted on the Japanese Experiment Module of the International Space Station. In the TANPOPO mission, we will expose and capture organic compounds, especially amino acids and their precursors in space. Amino acids are focused in our experiment, because they are the most important abundant organic compounds in living organisms, and thought as delivery into the earth from the outer-solar environments on meteorites, micrometeorites and/or comets. We would like to compare the stability in space of amino acids and their precursors in order to confirm that amino acids precursors especially complex organics synthesized under ice mantles of interstellar grains in dense cloud. Therefore, glycine, isovaline, hydantoin, ethylmethylhydantoin and complex organics formed in the simulated experiments of interstellar clouds will be exposed. In addition, cosmic dusts, which are plausible carriers of extraterrestrial organics will be captured in the TANPOPO mission without terrestrial contamination.

Hydrogen peroxide as driving agent for replication and evolution in the RNA World

Rowena Ball (The Australian National University, Canberra 0200, Australia). Email: Rowena.Ball@anu.edu.au
John Brindley (University of Leeds, Leeds LS2 9JT, U. K.) Email: J.Brindley@Leeds.ac.uk

The story of the relationship between hydrogen peroxide and life on earth is a complex one, which begins at least 3.6 billion years ago. In this presentation we report progress towards elucidating this relationship in its very earliest, prebiotic stages. In the cell-free ‘RNA World’ on the pre-biotic earth, RNA replication would require thermal cycling — heating to separate base-paired double strands alternating with a cooling phase to anneal complementary strands into newly replicated duplexes. What may have provided the necessary periodic thermal drive?

The early earth is believed to have been rich in hydrogen peroxide and thiosulfate. The redox reaction between these substances is a well-characterised thermochemical and pH oscillator. We set up and ran computational simulations, using experimentally measured thermokinetic and thermophysical data. The thermochemical oscillations turn out to have just the right period, 90–120 s, and temperature amplitude to drive replication and amplification of a 40-base RNA sequence [1]. In the RNA World, single RNA strands are believed to have had enzyme functionality. For nucleobases, a jpK a .pHj < 2 favours ribozyme activity of RNA and a jpK a .pHj> 2 promotes basepairing [2], thus pH cycling has the potential to aid and enhance RNA replication. We expanded the model to include the competitive and autocatalytic chemistry that governs the pH. In the output time series, the pH cycles between 3.2 and 6.8. The breakthrough of this research was obtained by applying insights gained from applied mathematics and chemical engineering to a fundamental problem of the origin of life. It demonstrates that an interdisciplinary approach can make game-changing advances in this field.

[1] R Ball, J Brindley (2014). Journal of the Royal Society Interface, 11, 20131052.
[2] R Krishnamurthy (2012). Accounts of Chemical Research 45(12), 2035–2044.

Chair: Frances Westall

Evolution and SETI (Evo-SETI) as Lognormal Stochastic Processes

Claudio Maccone[1,2]*

[1]*International Academy of Astronautics (IAA) ;* [2]*Istituto Nazionale di Astrofisica (INAF), Italy*
* E-mail : clmaccon@libero.it

Astrobiologists study how life might have evolved on other planets given that it did evolve on Earth. Similarly, SETI scientists try to discover a signal or just some signs of an Extra-Terrestrial (ET) Civilization, given the existence of our own Civilization. Thus, comparing the evolution of life on two different planets is a central issue of both Astrobiology and SETI. In both cases, we need a profound mathematical theory about the evolution of life on Earth, that we may then extrapolate to find out "where other planets stand" in Evolution. In recent papers (Maccone 2013, 2014) and in a book (2012) this author introduced a statistical theory embracing SETI, Darwinian Evolution and even Human History into a unified statistical vision, concisely called Evo-SETI (standing for "Evolution & SETI").

This theory's key facts are: 1) The statistical generalization of the Drake equation yielding the number N of communicating ET civilizations in the Galaxy. Assuming each input variable in the Drake equation to be a random variable, N was shown to approach the lognormal distribution as the number of inputs grows. Its mean value is the sum of the input mean values, and its variance is the sum of the input variances. 2) Geometric Brownian Motion (GBM), the stochastic process representing Evolution as the random increase of the number of Living Species on Earth in the last 3.5 billion years. This GBM (known in Mathematical Finance as "Black-Sholes" model) has a lognormal probability density function (pdf) and an exponential increasing mean value. Mass Extinctions are just temporary GBM all-lows. 3) The b-lognormal pdfs, i.e. lognormals starting at a positive instant b>0 rather than at zero. These b-lognormals were then "forced" by this author to have their peak value located on the exponential mean-value curve of the GBM ("Peak-Locus Theorem"). In Darwinian Evolution, this mathematical construction was shown to identify with Cladistics (Maccone 2013).

4) The (Shannon) Entropy of these b-lognormals is then the "degree of organization" reached by each living organism or group of living organisms, like historic human civilizations. Having understood this fact, even Human History may be cast into the language of b-lognormals more and more organized in time (i.e. having a smaller and smaller Entropy), and all these b-lognormals have their peaks located on the increasing GBM exponential. The exponential is thus the "trend of progress" in Human History. 5) But our most striking result is about the "Molecular Clock" of Evolution, i.e. the "constant rate of Evolution at the molecular level" as in Kimura's Neutral Theory of Molecular Evolution: the Molecular Clock identifies with Entropy since both grew linearly in time over the last 3.5 billion years.

In conclusion, we found a mathematical model for Evolution, SETI and History based on Entropy: it is given by a set of statistical equations using b-lognormal pdfs and lognormal stochastic processes.

References

Maccone C. (2013) SETI, Evolution and Human History Merged into a Mathematical Model, International Journal of
Astrobiology 12 (3) : 218-245.

Maccone C. (2014) Evolution and Mass Extinctions as Lognormal Stochastic Processes, International Journal of
Astrobiology, 2014, in press. A copy of the final PROOF is attached to the e-mail with this Abstract.
Maccone C. (2012) Mathematical SETI, a 724-pages book published by Praxis-Springer in the fall of 2012. ISBN, ISBN-10:
3642274366 | ISBN-13: 978-3642274367 | Edition: 2012

The History and Philosophy of Biosignatures

David Dunér[1,2]*

[1]*History of Science and Ideas, Lund University, Sweden ;* [2]*Centre for Cognitive Semiotics, Lund University, Sweden*

* David.Duner@kultur.lu.se

The study of the history and philosophy of astrobiology concerns the ideas and events that made it possible to think of other worlds and distant life. It traces the history of science and the development of new schools in philosophy. Its aim is to discuss the place of humanity in the Universe. But what does it mean to speak of the history and philosophy of astrobiology, and particularly the history and philosophy of biosignatures? What lines of research are there and what has been accomplished? (See e.g. Dunér, 2011; Dunér et al., 2012; Dick, 2012; Dunér et al., 2013) And why history? Why philosophy? What can be learned is the nature of what it is to be human. The search for life in the Universe touches on the essence of what it means to formulate a theory, grasp a concept, and have an imagination. This paper aims to clarify why history and philosophy are important for the self-understanding of astrobiology. Semiotics and philosophy of science will be especially useful for the study of biosignatures, when scientists interpret not life itself, but traces, signs and marks of life. It will discuss how it has developed and what deeper fundamental problems it faces. In short, the history of astrobiology is concerned with the evolution of human conceptions of the plurality of worlds (for the history of the debate on extraterrestrial life, see Dick, 1982; 1996; Guthke, 1983; Crowe, 1986; 2008).

References

Crowe, M. J. 1986. The Extraterrestrial Life Debate 1750–1900: The Idea of a Plurality of Worlds from Kant to Lowell. Cambridge: Cambridge University Press.

Crowe, M. J. 2008. The Extraterrestrial Life Debate, Antiquity to 1915: A Source Book. Notre Dame IN: University of Notre Dame.

Dick, S. J. 1982. Plurality of Worlds: The Origins of the Extraterrestrial Life Debate from Democritus to Kant. Cambridge: Cambridge University Press.

Dick, S. J. 1996. The Biological Universe: The Twentieth-Century Extraterrestrial Life Debate and the Limits of Science. Cambridge: Cambridge University Press.

Dick, S. J. 2012. “Critical issues in the history, philosophy, and sociology of astrobiology.” Astrobiology 12(10):906–927.

Dunér, D., ed. 2011. The History and Philosophy of Astrobiology: International Conference on Tycho Brahe’s island Ven, Sweden, September 27–28, 2011. Lund: The Pufendorf Institute of Advanced Studies.

Dunér, D., E. Persson, and G. Holmberg, eds. 2012. “The history and philosophy of astrobiology.” Special issue of Astrobiology 12(10).

Dunér, D., J. Parthemore, E. Persson, and G. Holmberg, eds. 2013. The History and Philosophy of Astrobiology: Perspectives on Extraterrestrial Life and the Human Mind. Newcastle-upon-Tyne: Cambridge Scholars Publishing.

Guthke, K. S. 1983. Der Mythos der Neuzeit: Das Thema der Mehrheit der Welten in der Literatur- und Geistesgeschichte von der kopernikanischen Wende bis zur Science Fiction. Bern: Francke.

Poster Presentations

1

Mapping Desert Varnish: A Hidden Signature

Rebecca Siddall

Utah's Capitol Reef petroglyphs are a literal signature of life: visual, creative, human. But they are cut from another, more elemental signature. The darkened rock crust around them - etched away by Native Americans centuries ago - is 'desert varnish', the composite name for a manganese or iron oxide sheen frequently deposited by the extremophile genus *Pedomicrobium* as a component of the crust.

Pedomicrobium's self-protective enzymatic processes let its species thrive in various extreme environments worldwide (temperature, pressure, desiccation, radiation). Such qualities have earned it a place on the BIOMEX project, in biofilm prepared by TU Berlin. Its performance may lead us closer to knowing whether it exists – or once existed – in desert varnish-type geologies far from Earth. Whatever BIOMEX reveals, there is clearly a need to locate other species that may have evolved into, from, or alongside the currently known *Pedomicrobium* species and strains.

Applying 'Mars Rover' principles to Google Street View, I have created a map of potential desert varnish sites across Utah, with forays into Nevada and Colorado for maximum climatological and geological diversity. My visual survey can afford to be flexible because each site – with a few exceptions on hiking trails – is visible and accessible from roads which are conveniently interconnected by the US highway system. The results from my desert varnish survey are allowing me to build a database of sites for exploration and sampling in the field, from Capitol Reef to the Valley of Fire.

2

Survival of *Deinococcus geothermalis* under simulated space and Martian conditions

Jan Frösler, Jost Wingender, Corinna Panitz, Elke Rabbow, Petra Rettberg, Hans-Curt Flemming

Jan Frösler, Biofilm Centre, Department of Chemistry, University of Duisburg-Essen, Universitätsstrasse 5, 45141 Essen, Germany; jan.froesler@uni-due.de

The bacterium *Deinococcus geothermalis* has developed a high tolerance against oxidative stress which makes it to our knowledge one of the most desiccation- and radiation-resistant organisms. Its resistance may allow the organism to survive even travelling through outer space.

This study is part of the space mission BOSS (Biofilm Organisms Surfing Space), which investigates the hypothesis that microorganisms benefit from being in their biofilm mode of life when exposed to a Martian or space environment, respectively. In preparation for BOSS, simulations were carried out at the Planetary and Space Simulation Facilities (PSI) at the German Aerospace Center (DLR) in Cologne, Germany, in which biofilms and planktonic cells of *D. geothermalis* were dried and then exposed to polychromatic UV irradiation in combination with vacuum or artificial Martian atmosphere, respectively. After exposure, the samples were rehydrated and subsequently analysed for survival by culture-dependent (plate counts) and culture-independent techniques (membrane integrity, ATP content, 16S rRNA presence).

The results suggest that *D. geothermalis* would be able to survive in space and on Mars for a certain period of time in both the biofilm and the planktonic mode. Exposure to simulated ambient conditions of space and Mars in the absence of light did not seem to affect viability of *D. geothermalis*. When irradiated with UV light, however, culturability decreased, with planktonic cells being affected more strongly than biofilms.

3

Phosphates from NWA 2975 shergottite – insights into the evolution of volatiles in Martian magma and their contribution to abiotic systems

Ewa Słaby[1], Richard Wirth[2], Hans-Jürgen Förster[2], Izabela Moszumańska[1]

[1] Institute of Geological Sciences, PAS, Warsaw, Poland
[2] Deutsches GeoForschungsZentrum, Potsdam, Germany

Magma degassing plays an important role in controlling the abiotic-system composition. Phosphates, such as volatile-bearing apatite and anhydrous merrillite, are frequently used to decipher magma composition and its degassing process. In NWA 2975, merrillite represents intermediate merrillite-–ferromerrillite solid solutions and fluorapatite is rich in Cl and water. Both phosphates have been indexed (HR TEM study). They reveal planar deformations or mosaicism of several, variably distorted and undistorted sub-domains reflecting shock induced deformation, suggesting that both species precipitated from residual magma prior to the shock event. Quenched, very porous melt drops of phosphate composition, containing silica and volatiles (with F predominating over Cl) occur in merrillite, but not in apatite. In apatite cracks, crystallization of residual, F-enriched and Cl-free melt is observed. Tiny, tile-shaped crystals (indexed as apatite) nucleated on the crack's walls and grow in parallel-oriented piles. The composition of host apatite shows the presence of both F and Cl in parental magma. Two apatite generations support the occurrence of volatiles in the melt during phosphate formation. Geochemical modelling shows that the parental magma was volatile poor. Volatile concentrations considerably increased during progressive fractional crystallization, however, Cl is mostly exhausted before its termination. Consequently, mainly F and water may be added to abiotic environment during degassing.

4

Assessing the feasibility to cultivate methanogens under Enceladus-like conditions

R.-S. Taubner[1,3], S. Rittmann[2], J.J. Leitner[1,3], C. Schlepper[2], M.G. Firneis[1,3], R. Hitzenberger[1,4]

[1] *Research Platform: ExoLife, University of Vienna, Austria*
[2] *Department of Ecogenomics and Systems Biology, University of Vienna, Austria*
[3] *Institute of Astrophysics, University of Vienna, Vienna, Austria*
[4] *Faculty of Physics, University of Vienna, Vienna, Austria*

Despite its small mean radius of only 252.1 ± 0.2 km (Thomas, 2010), Saturn's icy moon Enceladus is one of the most interesting objects in the Solar System concerning Astrobiology. At least since the third close flyby of NASA's Cassini spacecraft in July 2005, there has been no doubt about the evidence of a plume of emerging water vapour and small icy grains from warm fractures near the South Polar Region. The origin of the plume's material is still a much debated question. Here, we will follow common assumptions (Matson et al., 2012; Postberg et al., 2009) that the plume's source is a subsurface water aquifer which is (or at least was) in contact with the underlying rocky core.
Due to the actual gravity measurements of the spacecraft Cassini (Iess et al., 2014), Enceladus' interior structure and the conditions at the core-water-boundary are quite well assessable. We will perform experiments in the laboratory, where we will test the habitability of this environment concerning methanogens as suggested by McKay et al. (2008). Here, we will test different strains of methanogens in various temperature ranges for their feasibility to propagate in Enceladus-like conditions. Based on the observations obtained by the Cassini spacecraft concerning the plume compounds (Waite et al., 2009) we will produce a medium with a composition similar to the ocean composition of this icy moon which is far more Enceladus-like than in any (published) experiment before. The results of this project will deliver an important assessment on the possibility that extraterrestrial habitats may harbour life-as-we-know-it.

References:
Iess, L. et al. The Gravity Field and Interior Structure of Enceladus. Science, 344:78-80, April 2014. doi: 10.1126/science.1250551

Matson, D. L., Castillo-Rogez, J. C. , Davies, A. G., and Johnson, T. V. Enceladus: A hypothesis for bringing both heat and chemicals to the surface. Icarus, 221:53–62, Sept. 2012. doi: 10.1016/j.icarus.2012.05.031.

McKay, C. P. et al. The Possible Origin and Persistence of Life on Enceladus and Detection of Biomarkers in the Plume. Astrobiology, 8:909–919, Oct. 2008. doi: 10.1089/ast.2008.0265.

Postberg, F., et al. Sodium salts in E-ring ice grains from an ocean below the surface of Enceladus. Nature, 459:1098–1101, June 2009. doi: 10.1038/nature08046.

Thomas, P.C. Sizes, shapes, and derived properties of the saturnian satellites after the Cassini nominal mission. Icarus, 208:395–401, July 2010. doi: 10.1016/j.icarus.2010.01.025.

Waite Jr., J. H. et al. Liquid water on Enceladus from observations of ammonia and ^{40}Ar in the plume. Nature, 460:487–490, July 2009. doi: 10.1038/nature08153.

5

Enceladus: Biosignatures

Rocco L. Mancinelli[1,2], Christopher P. McKay[2], and Alfonso Davilla[2,3]

[1]BAER Institute, [2]NASA Ames Research Center, [3]SETI Institute, Moffett Field, CA, USA

Saturn's moon Enceladus is a new world for Astrobiology. Through the study of Enceladus' plumes new insights into its habitability will be gained. The four core parameters for life include: water, carbon, nitrogen, and energy; all were found in the plume. Carbon and nitrogen in the plume exist in forms easily usable by biological systems (CH_4, HCN, NH_3, H_2 , CO_2, and organics up to C_6). The first step to search for evidence of life is to define potential biosignatures for Enceladus.

If life exists on Enceladus it will most likely possess peptides containing prebiotic amino acids. The use of amino acids as a biosignature is attractive for three reasons: (1) They possess chirality and living systems primarily uses one stereoisomer; (2) the frequency distribution of amino acids in living systems is different from prebiotic chemistry; and 3) they can be detected by instruments that can fly on future missions. The frequency and abundance of amino acids in prebiotic chemistry and in meteorites is correlated with their Gibbs free energy with the simple amino acids (e.g., glycine and alanine) being the most abundant, whereas, the relative abundance of amino acids in biological systems promotes the synthesis of complex amino acids over simple ones. As a result, the relative ratios of the simple amino acids to complex amino acids along with their chirality in a sample can, in principle be used as a guide to distinguish between abiotic and biological sources. We hypothesize that the combination of homochirality and amino acid frequency distribution can be a biosignature for Enceladus.

6

Microbial life in extreme, Mars-relevant brines: liquid water does not imply habitability.

Mark Fox-Powell, Samuel J. Payler & Charles S. Cockell

UK Centre for Astrobiology, School of Physics and Astronomy, University of Edinburgh, Edinburgh, UK;

A considerable body of evidence indicates that hypersaline waters have been present on the surface of Mars, at least periodically, throughout the planet's history. This has encouraged comparisons with terrestrial brine environments, which are NaCl-rich and often densely populated by salt-tolerant microorganisms. Unlike terrestrial systems, however, the acidic weathering of ultramafic basalt on Mars produced fluids rich in magnesium, iron and sulphates. Brines formed from such fluids impose physicochemical stresses drastically different to those experienced by NaCl-tolerant organisms on the Earth. Since analogous terrestrial environments do not exist, we have explored Martian brine habitability by synthesising geochemically-relevant fluids in the laboratory and inoculating them with diverse, salt-tolerant microbial communities. Our data show that communities growing in Mars-relevant brines differ fundamentally from those commonly found in terrestrial NaCl-rich environments. Furthermore, we show that some brine compositions are uninhabitable, despite possessing biologically permissive water content. We propose that the dominance of NaCl-enriched environments on Earth has biased our understanding of the capacity for life in high salt. Our data show that water activity (the thermodynamic availability of water) is not a sufficient predictor of habitability on Mars. These findings are critical both in determining regions of present-day habitability and in identifying candidate habitable paleoenvironments.

7

Limits of survival: The effect of mars-like conditions, irradiation and humidity on the vitality of bryophyte species

Annelie Fiedler[1], Björn Huwe[1], Jean Pierre de Vera[2], Jasmin Joshi[1]

[1]University of Potsdam, Institute for Biochemistry and Biology, Biodiversity research and Botany Maulbeerallee 1, 14469 Potsdam, Germany [2]German Aerospace Center (DLR), Institute of Planetary Research, 12489 Berlin, Germany

Due to their ability of desiccation tolerance Bryophytes are able to colonize extreme habitats. Pretests show the remarkable resistance of *Grimmia sessitiana* to simulated space vacuum, Mars-like atmosphere, extreme temperatures, UVC radiation and desiccation. These are results from the BIOMEX-project (Biology and Mars Experiment)- a space experiment on the exposure platform EXPOSE-R2 on the International Space Station (ISS) (unpublished).

As a contribution to the BIOMEX-project, we investigate in addition to *Grimmia sessitiana,* other species that may survive simulated mars-and space-like conditions. This work aims to give an overview about survival, damage of photosynthesis-apparature and germination of the examinated species after exposure to (I) mars conditions and (II) earth conditions under different doses of irradiation and different levels of humidity. Therefore different moss species with different morphological adaptations to extreme environmental conditions are used. The plant material was taken from *Grimmia sessitana ,Grimmia alpestris, Grimmia pulvinata, Ceratodon purpureus, Tortula muralis* and *Polytrichum piliferum* as well as spores from *Grimma pulvinata.*To simulate mars-conditions and UV- irradiation we used the Mars simulation Facility of the German Aerospace Center (DLR) in Berlin.

8

The anaerobic community of an estuarine environment: an analogue for life on Mars.

E. Curtis-Harper, V. Pearson, S. Schwenzer, K. Olsson-Francis

The Open University, Walton Hall, Milton Keynes, MK7 6AA, United Kingdom

The first step in finding potential extant, and/or extinct, life on Mars is to understand the potential biological processes that may have occurred on Mars. This is dependent on identifying and characterising microbial life in suitable terrestrial analogue environments. Chemolithotrophic anaerobic microorganisms, such as methanogens, are ideal organisms for investigating potential life on Mars.

In this study, we used a community of chemolithotrophic anaerobic microorganisms, which were isolated from below the redox potential discontinuity (RPD) layer of the River Dee estuary, UK. The anaerobic conditions, the 11-15˚C temperature and high salinity make the sub-RPD zone an ideal analogue for the Martian subsurface. Using 454 sequencing we investigated the composition of the microbial community which included sulfate reducing bacteria. Anaerobic growth experiments were conducted with a basalt and aegirine growth medium, which were used as an analogue for the composition of the Rocknest site on Mars.

The microbial community was able to grow, utilising the bio-essential elements in the growth medium. The dissolution kinetics were determined by measuring the release of key elements, such as Si, Ca, K, Fe in the growth medium with ICP-AES and growth was measured by cell counts

The results from this study demonstrate that the microbial community below the RPD can act as an informative analogue in studies of Martian habitability and life detection.

9

Paradigm Shift Hypothesis: a case for RNA's influence on life on Earth

Sohan Jheeta

NoR HGT & LUCA, 1 Scott Hall Crescent, Leeds LS7 3RB, UK

Sohan7@ntlworld.com

In an historic context, genetic inheritance was thought to be carried by proteins, although this was never conclusively proven, nor is it likely to be. The breakthrough came in 1953 when Watson and Crick discovered that hereditary coding was actually contained in the series of bases, namely adenine, thymine, guanine and cytosine which are strung together to form a DNA molecule. This permanently imbedded the idea of the existence of DNA/protein life forms on Earth in the scientific community (Crick, 1968., Poole *et al*., 1998, Bada, 2004). Current literature and research would seem to 'rubber stamp' this position. How true is this credo, that all life forms are DNA/protein and not RNA/protein centred? Much has been written about RNA, beginning with the speculation by Gilbert (1986) of an RNA world, where RNA life forms may have inhabited the Earth and also that RNA may have dual properties - acting both as a genetic information carrier as well as a catalyst (ribozyme); this was eventually confirmed independently by both Altman (1989) and Cech (1981), joint Nobel Laureates in chemistry (1989). Further, Poole *et al*., (1998) hypothesised the presence of pre-RNA and, Lezcano and Forterre (1999) speculated the existence of an organism called the last universal common ancestor (LUCA). During the pre-RNA, RNA and LUCA eras, rudimentary proteins were also present and thus it was that the LUCA was an RNA/protein organism. There is ample evidence from various phylogenetic studies that there would have been a LUCA which was present at the dawn of the first emergence of the three domains of life, namely Archaea, Bacteria and Eukarya (Woose, 1990). However, the concept of the possibility of RNA/protein 'dominated' life forms remained consigned to the history of the LUCA epoch and the allure of DNA/protein became so entrenched in the scientific psyche that RNA/protein has never been considered as a serious contender for the controlling of life forms on Earth.

With the continued unearthing of new roles for both DNA and RNA – eg the activities of non-coding portions of these nucleic acids – it is now becoming clear that there are no such things as 'junk' nucleic acids; everything in the cell has a part to play and is sooner or later utilised or activated in one way or another. This is particularly true of RNA as the growing list of its functions, from acting as a simple co-enzyme to a macro-machine as in the case of ribosomes, clearly demonstrates. Moreover, studies on *Oxytricha trifallax*, show that RNA is still very much in control of that particular ciliate (Swart, 2013). In addition to highlighting the relevance of findings relating to RNA, this oral presentation will put a case for a paradigm shift in favour of cellular life forms being organised and controlled by RNA/protein.

References

Watson, J. D and F. H. C. Crick (1953). "A structure for deoxyribose nucleic acid." Nature. **171:** 737–738

Altman, S., M. F. Baer *et al*., (1989). "Catalysis by the RNA subunit of RNase P—a minireview." Gene. **82 (1):** 63–4. doi:10.1016/0378-1119(89)90030-9.

Cech, T. R., A. J. Zung *et al* (1981). "In vitro splicing of the ribosomal RNA precursor of Tetrahymena: Involvement of a guanosine nucleotide in the excision of the intervening sequence." Cell. **27:** 487–496.

Crick, F. H. C., (1968). “The origin of the genetic code.” Journal of Molecular Biology. **38:**367-379

Pool M. A., D. C. Jaffares *et al*., (1998). “The path from the RNA world.” Journal of Molecular Evolution **46:**1-17

Bada J. L. (2004). “How life began on Earth: a status report.” Earth and Planetary Science Letters. **226:** 1-15.

Gilbert, W. (1986). “The RNA world.” Nature. **319:** 618

Lazcano A., P. Forterre (1999). “The molecular search for the last common ancestor.” Journal of Molecular Evolution. **49:** 411-412

Woese C. R., O. Kandler *et al*., (1990). “Towards a natural system of organisms: proposal for domains Archaea, Bacteria and Eukarya.” Proceedings of the National. Academy of Sciences. **87**: 4576-4579

Swart E. C., J. R. Bracht et al (2013). “The *Oxytricha trifallax* macronuclear genome: A complex eukaryotic genome with 16,000 tiny chromosomes.” PLOSBiology. **11(1)**: e1001473

10

Iron-oxidising thermoacidophilic archaeon *Metallosphaera sedula*: insights into astrobiological application

Ziga Zebec[1], Simon Rittmann[1], Melina Kerou[1], Christa Schleper[1], Tetyana Milojevic[1, 2]

[1]*Archaea Biology and Ecogenomics Division, University of Vienna, Austria*
[2]*Department of Biopysical Chemistry, University of Vienna, Austria*

Extremophiles represent an enigmatic link between terrestrial and extraterrestrial environments, providing insights about life in outer space. Such microbes are found at the edge of living limits and considered among the first microorganisms on Earth with their severe and ancient environments, serving as models for life under the harsh conditions on extraterrestrial bodies. Numerous orbital and *in situ* missions to Mars have demonstrated that the planet was habitable in the past with chemolitotrophs as the most probable life forms existing in extreme environments. Due to the abundance of iron and sulphur minerals on Mars, iron-sulphur transforming microorganisms are considered likely models of putative Martian living entities.

Fe-oxidizing archaeon *Metallosphaera sedula* inhabits extreme environments, flourishing in hot acid and exhibiting unusual heavy-metal resistance. This chemolithotrophic archaea thrives at 73°C and pH2, utilizing energy derived from metal oxidation. Iron and sulphur compounds are preferentially requited for its growth. Stimulated by its exceptional physiological properties, we have set out to assess the survival potential of *M. sedula* by investigating the 1) viability of this archaea living on and interacting with minerals of not terrestrial origin and 2) its survival under the influence of UV-irradiation. Initial results demonstrate meteorite-supported growth of *M. sedula* and an effect of exposure to UV-radiation on this archaea.

Further work will associate multidisciplinary tools to characterize unusual resistance and metabolic pathways of *M. sedula* in the scope of astrobiology.

11

Biosignatures on Mars, a review

Frances Westall and Frédéric Foucher

CNRS-Centre de Biophysique Moléculaire, Orléans, France

We now have three astrobiology missions on Mars (Curiosity) or forthcoming (ExoMars 2018, Mars 2020). All are aiming to search for traces of past life in Noachian or earliest Hesperion terrains. In this context, we review the kinds of biosignatures likely to be found on Mars and compare the techniques that can be used *in situ* on the planet with what could be done in the laboratory and, respectively, the kinds of information that could be obtained.

Our premise is that, martian life, if present and fossilised, is likely to have been very primitive and probably based on chemotrophy, not phototrophy. This rationale is based on the fact that, although Mars was relatively habitable in its early history, the lack of continuous and connected habitability placed great constraints on the kinds of life forms that could have developed on the planet (Westall et al., 2013). In comparison, during the same time period, the Earth was a continuously habitable planet upon which photosynthetic life could slowly evolve.

Both the ExoMars and Mars 2020 missions in particular carry instruments that are well adapted to the *in situ* search for traces of life. These range from large to macro-scale context instrumentation (imaging, elemental and mineralogical analyses and mapping), to analyses of organic molecules in drilled samples. Despite their obvious limitations compared to terrestrial instrumentation, the suites of instruments on each mission are powerful and should be able to provide information on the presence of organic (and possibly morphological) traces of life and possibly, though the isotopic analysis of carbon, some details regarding the metabolic strategies of the martian microorganisms. Obviously, more detailed information would be obtained through *in situ* analysis of samples of fossiliferous martian rocks on Earth.

Westall, F., Loizeau, D., Foucher, F., Bost, N., Bertrand, M., Vago, J., Kminek, G., 2013. Habitability on Mars from a microbial point of view. Astrobiology, 13, 887-897.

12

Effect of heavy metal ions on the antioxidant properties of *Mentha spicata*

Tara Pokhriyal, Javaid Ahmad, Suresh Sharma, Deepika singh

Lovely Professional University, Punjab, India

Oxidative stress arises when there is a marked imbalance between the production and removal of reactive oxygen species (ROS) in favor of the prooxidant balance, leading to potential oxidative damage. ROSs were considered traditionally to be only a toxic byproduct of aerobic metabolism. Plants can't move away and are therefore continuously confronted with unfavorable environmental conditions (such as soil salinity, drought, heat, cold, flooding and heavy metal contamination). Among heavy metals, cadmium (Cd),Arsenic(As), Lead(Pb) and Nickel(Ni) is a non-essential and toxic metal, rapidly taken up by roots and accumulated in various plant tissues . In the present study, the effects of heavy metals generating antioxidative defense systems (i.e. total phenolics estimation,antioxidant activity assay etc) were studied in the leaves of *Mentha* plants grown in soil polluted with heavy metals (Cd, Pb, As, Ni,) Treatment with metal caused the problem of an elevation in its bioavailability in soil and its concentration in leaves and stems. The antioxidant responses appeared to be metal specific. The elevation of non enzymatic activity in leaves was the only more general reaction to metal exposure, which is seen by analyzing the effects of soil metal contamination on *Mentha spicata*.

13

Formation of Iron Porphyrins Under Putative Prebiotic Conditions

Stefan Fox*, Hannes Pleyer, Henry Strasdeit

Department of Bioinorganic Chemistry, Institute of Chemistry, University of Hohenheim, 70599 Stuttgart, Germany
* E-mail: Stefan.Fox@uni-hohenheim.*de*

On the early Archean Earth, volcanic islands may have presented promising locations for chemical evolution. They provided a large variety of physical and chemical conditions such as a wide range of temperatures, wet–dry cycles in tide pools, salty and fresh water, lava–seawater interactions, reducing gases and lightning in volcanic eruption clouds, minerals and dissolved metal ions. In previous laboratory experiments, simulating prebiotic volcanic islands conditions, we have demonstrated that pyrroles and subsequently oligopyrroles, including porphyrins, may have formed abiotically [1].
Metal complexes of porphyrins have key functions in the basic metabolisms of modern organisms. Particularly heme, which represents a group of iron porphyrins, is widespread as a biological electron carrier. It seems plausible that iron porphyrins were among the earliest biomolecules, or even existed before in the "prebiotic soup" and in protometabolisms. Currently, we are experimentally investigating whether iron porphyrins could have formed abiotically under the putative conditions of early Archean volcanic islands. For this purpose, wet–dry cycles are simulated in which the model compound octaethylporphyrin is treated with potential iron sources such as iron-bearing minerals and rocks under strict exclusion of oxygen. First results from these experiments will be presented.

[1] S. Fox, H. Strasdeit, A possible prebiotic origin on volcanic islands of oligopyrrole- type photopigments and electron transfer cofactors. Astrobiology 13:578–595 (2013).

14

Raman spectroscopy: Caution when interpreting organic carbon from oxidised environments

Connor Brolly[1], John Parnell[1] & Stephen Bowden[1]

[1]*University of Aberdeen*

Oxidation is ubiquitous on Mars and has been observed by MER Opportunity at Meridiani Planum [1] and MSL Curiosity [2] at Gale Crater, and more widely at Gale Crater by CRISM [3]. If organic carbon (one of the building blocks of life) is present within the Martian sediments, it is very likely that it will have experienced some oxidation [4]. Understanding the effect oxidation has on carbon is extremely important when testing and selecting instrumentation for future surface landers on Mars.

Analysis of oxidised carbon rich rocks from Caithness, NE Scotland (Devonian) by Raman spectroscopy shows that oxidised carbon spectra are markedly different from non-oxidised spectra. The most obvious difference is in the carbon D band morphology, which is extremely intense and broad compared with non-oxidised spectra. It also displays a downward shift in band position from $1350 cm^{-1}$ to $1320 cm^{-1}$. Analysis of hematite shows a band occurring around $1320 cm^{-1}$ and is attributed to magnon scattering [5]. Therefore the change in D band morphology and position is interpreted as a hematite overprint, rather than a change in structural order of carbon as a result of the oxidation process. Consequently, caution must be taken when applying Raman spectroscopy for organic carbon analysis in oxidised terrestrial and extraterrestrial environments, including on Mars.

[1] J. A. Hurowitz et al, “Origin of acidic surface waters and the evolution of atmospheric chemistry on early Mars,” *Nat. Geosci.*, vol. 3, no. 5, pp. 323–326, Apr. 2010.

[2] D. F. Blake et al, “Curiosity at Gale crater, Mars: characterization and analysis of the Rocknest sand shadow.,” *Science*, vol. 341, no. 6153, p. 1239505, Sep. 2013.

[3] A. A. Fraeman et al, “A hematite-bearing layer in Gale Crater, Mars: Mapping and implications for past aqueous conditions,” *Geology*, vol. 41, no. 10, pp. 1103–1106, Jul. 2013.

[4] R. Navarro-González et al, “Reanalysis of the Viking results suggests perchlorate and organics at midlatitudes on Mars,” *J. Geophys. Res.*, vol. 115, no. E12, p. E12010, Dec. 2010.

[5] D. L. A. de Faria et al, “Raman Microspectroscopy of Some Iron Oxides and Oxyhydroxides,” *J. Raman Spectrosc.*, vol. 28, no. February, pp. 873–878, 1997.

15

Tolerance of Archaea and Bacteria against perchlorate

Petra Rettberg[1,*], Maria Bohmeier[1], and Kristina Beblo-Vranesevic[1]

1 German Aerospace Center (DLR e.V.), Institute of Aerospace Medicine, Radiation Biology Division, Linder Hoehe, 51147 Cologne, Germany.

* Corresponding author: Dr. Petra Rettberg, petra.rettberg@dlr.de

Due to the ability of (hyper-) thermophilic Bacteria and Archaea to live in extreme habitats on Earth (e.g. boiling acidic springs, black smoker chimneys, hyper-salinic brines) one could suggest, that these organisms can also outlast other harsh conditions, e.g. prevailing in space or on Mars. On Mars the occurrence of different utilizable nutrition components is limited. The Phoenix lander detected significant amounts (0.4 – 0.6 %) of perchlorate ions in martian soil.

Therefore, we examined the ability of the perchlorate metabolizing Archaeon *Archaeoglobus fulgidus* as well as phylogenetically deep-branching Bacterium *Hydrogenothermus marinus* to survive and grow in the presence of perchlorate ($NaClO_4$).

The investigated microorganisms were able to tolerate high concentrations of $NaClO_4$ without any changes in their growth pattern. After the addition of 280 mM perchlorate *H. marinus* showed significant changes in cell morphology. This organism is normally growing as single motile short rods; treated with high concentrations of perchlorate long chains up to 20 cells were built. *A. fulgidus* can tolerate concentrations up to 300 mM. Furthermore, it was investigated if the known desiccation tolerance of *A. fulgidus* and *H. marinus* is influenced by a previous treatment with perchlorate.

In summary (Hyper-) Thermophiles have so far unknown high tolerances against cell damaging treatments and may serve as model organisms for future space experiments.

16

The Question of Life: Between Anthropology and Astrobiology

Istvan Praet

University of Roehampton, London

The discovery of the Americas in the late 15th century and contemporary space exploration have at least one thing in common. In Renaissance Europe a fierce debate raged over whether those exotic Indians whom Columbus first encountered were human or something else altogether. This basic uncertainty echoes astrobiologists' worry that even if they find alien life they could still fail to discern it, as it may be unrecognizably different from the terrestrial kind of life they are familiar with. Reflecting on the definition of life is therefore a central issue for them, just as pondering the definition of humanity was very much at the forefront of theological debates during the early days of the Spanish Conquista. This paper proposes to address the question of life from an anthropological perspective. It provides an overview of recent advances in research on animism and documents how so-called indigenous people distinguish between what is alive and what is not. The aim is not to offer a catalogue of non-Western notions of life but to convey a sense of the unsuspected arbitrariness of its modern biological conception and to draw attention to its historical roots in the Romantic period. In the Age of Discovery, Pope Paul III eventually *decided* that American Indians were human; this precedent leads one to wonder in how far the attribution of alive-ness is a self-evident fact or a human decision. More generally, the paper reflects on how the social sciences - and anthropology in particular - can contribute to the astrobiological enterprise.

17

Primary sequence control in prebiotic peptide formation *via* chemical and physico-chemical mechanisms.

Bryant, D. E.[1], Kee T. P.[1]

[1] *University of Leeds, School of Chemistry, Woodhouse Lane, Leeds, West Yorkshire, LS2 9JT, UK.* d.bryant@leeds.ac.uk.

Several routes have thus far been identified for the prebiotically plausible formation of peptide bonds, essentially a dehydration, usually involving surfaces or activating agents. Notable among these is the “salt induced peptide formation” (SIPF) proposed by Bernd Rode (1) in which a preference is found for a given amino acid sequence in peptide bond formation.

We have proposed the phosphorus anhydride pyrophosphite as a prebiotically plausible energy currency molecule (2) and we find it to be an efficient agent for the coupling of amino acids to form peptides. Although the mechanisms involved in peptide bond formation differ substantially between SIPF and pyrophosphite, the same sequence is favoured in both cases. However we find with pyrophosphite it is possible to direct the sequence formed by controlling the pH. Additionally the coupling of serine does not occur using pyrophosphite due to the interference of the side chain alcohol yet peptides can be formed including serine provided the serine does not form the N terminus.

1. J. Bujdak and B.M. Rode, *Catalysis Letters* Vol. 91, Nos. 3–4, December 2003

2. D.E.Bryant *et al. Geochimica et Cosmochimica Acta* 109 (2013) 90–112.

18

Microbially induced rock weathering in the altered fluid dynamics of reduced gravity

N. Nicholson[1], C. Cockell[1]

[1]*UK Centre for Astrobiology, School of Physics and Astronomy, The University of Edinburgh, UK*

The behaviour and mixing regimes of water in microgravity are substantially different to the liquid conditions that bacteria have evolved with on Earth. Outside of gravity's influences there are no longer the convective flows driven by temperature and density differences, and, without hydrostatic pressure, sedimentation and buoyancy forces are eliminated, along with the tendency of liquid to deform under its own weight. Bacteria have insufficient mass to be directly affected by the absence of gravitational force, but they are sensitive to the secondary environmental effects of microgravity. It is possible that in slower mixing regimes restrictions in the availability of oxygen and nutrients, and lack of waste dispersion, could inhibit growth. Conversely, previous flight experiments have shown that positive morphological changes and gene expression can occur in bacteria; an investigation into the biofilm formation, gene expression, and growth parameters are additional aims.

Sphingomonas desiccabilis, a strain of rock-weathering heterotrophic bacteria isolated from desert environments, was chosen to explore how these altered liquid conditions affect the ability of bacteria to access and metabolise nutrients in rocks. This species has a resistance to temperature and desiccation stress which makes them a suitable test subject for space-flight. The experimental equipment, optically clear biomining reactors, are being tested to establish the optimum parameters for the growth of the organisms, and will be flown on parabolic flights and on board the International Space Station for exposure to microgravity. Biomining, a successful industry on Earth, could be a useful method for extracting useful minerals from asteroids, and is a potential application for this research alongside the fundamental physical questions of how solid, liquid, and living matter interact in microgravity.

19

Compartmentalization of the formose reaction to test metabolism-first theories on the origin of life

Turk-MacLeod, R.[1], Woronoff, G.[1], Nghe, P.[1], Szathmáry, E.[2], Griffiths, A.D.[1]

[1]Laboratoire de Biochimie, École Supérieure de Physique et de Chimie Industrielles de la Ville de Paris, Paris, France;

[2]Parmenides Foundation, Pullach/Munich, Germany

Metabolism-first theories on the origin of life suggest that there may have been prebiotic systems capable of propagation and Darwinian evolution that were not dependent on genetic, nucleotide-based replication. However, to date metabolism-first theories are not supported by experimental evidence. We are testing this idea experimentally by observing the formose reaction compartmentalized in protocell analogues. Using high-throughput microfluidic techniques, we react a simple formaldehyde feedstock in aqueous microdroplets, which results in the compartmentalized formation of various carbohydrates. We are investigating size changes of formose reaction-containing droplets as a function of reaction efficiency; droplet swelling correlates with complexity of carbohydrate products, and thus may serve as a mechanism for selection of metabolic protocells. Further analysis of swollen and subsequently split droplets will determine if there is compositional heredity across generations of protocells.

20

Tracking the earliest water in the solar system via oxygen isotope analyses of carbonates in CM carbonaceous chondrites

P. Lindgren[1], N.A. Starkey[2], I.A. Franchi[2], D.F. Mark[3], and M.R. Lee[1].

[1]*University of Glasgow*, [2]*Open University*, [3]*SUERC*

The first water in the solar system became available when H_2O-ice melted on small protoplanetary bodies within 4 Ma after their accretion within the solar nebula [1]. It is possible to trace the conditions and the relative timing of these early fluids through oxygen isotope analyses of secondary carbonate minerals that formed during aqueous alteration of carbonaceous chondrites [2,3,4].

We have analysed the O-isotopes of calcite in two CM carbonaceous chondrites (LAP 031166 and Mighei) using a NanoSIMS 50L at the Open University, to see if the O-isotope composition varies between (i) the two meteorites that are aqueously altered to various degrees and (ii) different petrographic types of calcite. Results show that the two CMs have the same general trend of oxygen isotope ratios but that the data vary substantially between different petrographic types of calcite within the individual CMs. This intra-meteorite variation may be due to carbonate mineralization during discrete pulses of aqueous solutions with changing compositions at different points in time [5,6] or it can reflect changes in temperature [7].

(1) Fujiya et al., Nat. Comm., 2012 (2) Clayton & Mayeda, EPSL, 1984 (3) Benedix et al., GCA, 2003 (4) Horstmann et al., LPSC, 2014 (5) Tyra et al., GCA, 2012 (6) Lee et al., GCA, 2013 (7) Guo & Eiler, GCA, 2007.

21

ARBEX - Archaeal and bacterial extremophiles onboard the international space station ISS

Maximilian Mora, Daniel Eckl, Michael Mauermeier, Christine Moissl-Eichinger

The International Space Station (ISS) represents a special living area for humans and accompanying microorganisms under extreme conditions, almost completely sealed off from the outside world. In such an environment regular monitoring of the microbial population is mandatory to assess eventual risks for the crew´s health or for the integrity of the spacecraft itself and to enable appropriate countermeasures if needed. The ARBEX project is designed to look beyond the confinements of the regular, standardized, microbial monitoring and aims for microorganisms yet uncultured onboard the ISS. The main focus lies on the detection of hardy, extremophilic bacteria and archaea via different cultivation assays and state-of-the-art molecular analyses. The obtained results will be compared to the cultivable and uncultivable microbiome of ground controls (i.e. spacecraft assembly clean rooms). The obtained isolates will be analyzed with regard to their physiology and resistances against e.g. (UV- and γ-) radiaton, desiccation and antibiotics. On this poster, the ARBEX project will be introduced in detail. We will also present the analysis of the first ground-control, namely the S5C clean room in Kourou, French Guiana, which was sampled in March this year. At least 40 different microbial isolates were obtained under different conditions, such as e.g. high and low pH values and oligotrophic medium. This assortment of microbes will be the baseline for comparative analyses with the ISS microbiome.

22

How to increase the credibility and ease the investigation of biosignatures in TOF-SIMS mass spectra?

Nikolas Tsakonas[1], Elias Chatzitheodoridis[1,*], Stefanos Kilias[2], and Ian Lyon[3]

[1]*Department of Geological Sciences, School of Mining and Metallurgical Engineering, National Technical University of Athens, Athens, Greece*
[2] *National Kapodistrian University of Athens, Department of Economic Geology and Geochemistry, Panepistimiopolis, Zographou, 157 84 Athens, Greece*
[3]*School of Earth, Atmospheric and Environmental Sciences, The University of Manchester, Manchester, UK*

*Corresponding author: Elias Chatzitheodoridis, *email address*: eliasch@metal.ntua.gr, *telephone*: +302107722092, *mobile*: +306945779492

TOF-SIMS mass spectra are labour intensive to interpret because of the very large number of peaks that are in the mass spectrum. In a previous work we concluded that it is possible to interpret TOF-SIMS mass spectra in detail, however, interpretation requires powerful proprietary software to handle the information (Chatzitheodoridis *et al*., 2005) and a perfect mass calibration (Antonopoulou-Athera *et al.*, 2011). Only then fully automated interpretation can be performed, also resulting in detailed chemical patterns that can be useful for biosignature interpretation.

Currently, biosignature interpretation is performed using a small number of characteristic peaks that are compared with pure, isolated biochemical phases, often assisted by statistical techniques, or by labelling specific molecules. Biochemical phases that have been investigated in the literature include proteins and their aminoacids (Quong *et al.*, 2005), extracellular polymeric substances (de Brouwer *et al.*, 2006), lipids in tissues and cells (Altelaar *et al.*, 2006; Besinger *et al.*, 2006; Thiel *et al.*, 2007a and 2007b, Leefmann *et al.*, 2013), and PAHs in meteorites (Stephan *et al.*, 2003; Thiel and Sjövall, 2011). A general conclusion is that there are no unique peaks that are characteristic of the different biological samples. Mass spectra are further complicated by the large number of molecular fragments, the absence of repeatability, and by artefacts (Quong *et al.*, 2005). Contamination is also common in the samples, and they should be considered when studying geobiological and astrobiological samples (Thiel *et al.*, 2007a), therefore its signatures should be also included in the database.

We have assembled all currently available information in the literature and have combined them with an existing database that has been developed in our lab, which is accessed through proprietary software that handles the TOF-SIMS mass spectra and assists in their interpretation (*spaceTOF*; Chatzitheodoridis *et al*., 2005). This is a significant effort, especially when one considers the lack of reference data, especially for compounds that could be of interest to astrobiology (Thiel *et al.*, 2007a). We test the database on new, high-resolution data acquired from polished sections of Quaternary hematite cement from the Cape Vani Mn-Fe (Ba) deposit, Milos island, Greece (Kilias *et al.*, 2013), which has petrified colonies of cyanobacteria. Then, we group organic molecules of similar nature and we compare the acquired intensity patterns. These patterns in their general appearance are very systematic between different samples; however, there is potential for a more precise interpretation when searching for small differences in the full set of mass peaks of the molecular species.

References:

1. Altelaar, A.F.M., Klinkert, I., Jalink, K., de Lange, R.P.J., Adan, R.A.H., Heeren, R.M.A., and Piersma, S.R. (2006) Gold-enhanced biomolecular surface imaging of cells and tissue by SIMS and MALDI mass spectrometry. *Anal. Chem.*, 78:734–742.

2. Antonopoulou-Athera, N., Mavrogiannidou, I., Chatzitheodoridis, E., Lyon, I., and Kilias, S. (2011) Interactive handling of biosignature patterns for the interpretation of TOF-SIMS mass

spectra. Poster presented at the *11th European Workshop on Astrobiology (EANA11)*, 11-14 July 2011, Köln, Germany.

3. Biesinger, M.C., Miller, D.J., Harbottle, R.R., Possmayer, F., McIntyre, N.S., and Petersen, N.O. (2006) Imaging lipid distributions in model monolayers by ToF-SIMS with selectively deuterated components and principal components analysis. *Applied Surface Science*, 252:6957–6965.

4. Chatzitheodoridis E., Lyon I., Vgenopoulos A. (2005) Interactive geochemistry in the micro- and submicron scale: a visual software tool for ion map extraction, manipulation and analysis from TOF-SIMS spectra. IMA05, Crete, Greece, 2-6 Oct. 2005.

5. De Brouwer, J.F.C., Cooksey, K.E., Wigglesworth-Cooksey, B., Staal, M.J., Stal, L.J., and Avci, R. (2006) Time of Flight-Secondary Ion Mass Spectrometry on isolated extracellular fractions and intact biofilms of three species of benthic diatoms. *J. of Microbiological Methods*, 65:562–572.

6. Kilias, S.P., Chatzitheodoridis, E., Lyon, I. (2013), "Morphological and chemical evidence of ferruginous microbialites in the Quaternary Cape Vani (Fe-Ba-)Mn-oxide deposit, Milos, Greece: implications for biomineralogy", in *Proceedings of 13th International Conference of the Geological Society of Greece,* September 5-8 2013, Chania, Crete, Greece.

7. Leefmann, T., Heim, C., Kryvenda, A., Siljeström, S., Sjövall, P., Thiel, V. (2013) Biomarker imaging of single diatom cells in a microbial mat using time-of-flight secondary ion mass spectrometry (ToF-SIMS). *Organic Geochemistry*, 57:23–33.

8. Quong, J.N., Quong, A.A., Wu, K.J., and Kercher, J.R. (2005) A Signature-Based Method to Distinguish Time-Of-Flight Secondary-Ion Mass Spectra from Biological Samples. In *Chemistry & Biodiversity*, 2:1495–1502.

9. Stephan, T., Jessberger, E.K., Heiss, C.H., and Rost, D. (2003) TOF-SIMS analysis of polycyclic aromatic hydrocarbons in Allan Hills 84001. *Meteoritics & Planetary Science*, 38:109–116.

10. Thiel, V. and Sjövall, P. (2011) Using time-of-flight secondary ion mass spectrometry to study biomarkers. *Annual Review of Earth and Planetary Sciences*, 39:125–156.

11. Thiel, V., Heim, C., Arp, G., Hahmann, U., Sjövall, P., and Lausmaa, J. (2007b) Biomarkers at the microscopic range: ToF-SIMS molecular imaging of Archaea-derived lipids in a microbial mat. *Geobiology*, 5:413–421.

12. Thiel, V., Toporski, J., Schumann, G., Sjövall, P., and Lausmaa, J. (2007a) Analysis of archaeal core ether lipids using Time of Flight–Secondary Ion Mass Spectrometry (ToF-SIMS): Exploring a new prospect for the study of biomarkers in geobiology. Geobiology, 5:75–83.

23

Chlorite and other clay minerals on Mars: evidence from Nakhla meteorite

Elias Chatzitheodoridis[1], Sarah Haigh[2], and Ian Lyon[3]

[1]*Department of Geological Sciences, School of Mining and Metallurgical Engineering, National Technical University of Athens, Athens, Greece*
[2]*School of Materials, The University of Manchester, Manchester, UK.*
[3]*School of Earth, Atmospheric and Environmental Sciences, The University of Manchester, Manchester, UK.*

*Corresponding author: Elias Chatzitheodoridis, *email address*: eliasch@metal.ntua.gr, *telephone*: +302107722092, *mobile*: +306945779492

Nano-crystalline iron-rich saponitic clay has been found to exist in Nakhla, most probably as in-filling of a hollow ovoid inside amorphous mesostasis of rhyolitic composition (Chatzitheodoridis *et al.*, 2014). The hollow ovoid in Nakhla is interpreted to be the result of a shock event from a bolide impact that induced circulating hydrothermal fluids with sharp temperature gradients in the subsurface of Mars, which variably altered the parent rock. This seems to be more evident now, with the additional discovery of two phases of phyllosilicate minerals, one of which is an iron-rich chlorite, and the other is probably a mixed-layer phyllosilicate. These phyllosilicates are located in the same thin section of Nakhla, very close to where the ovoid was also found (Chatzitheodoridis *et al.*, 2014).

Chlorite is a very common hydrous, layered silicate mineral on Earth, very similar in nature to micas. It is found in low to middle grade metamorphic rocks, in sedimentary rocks during their diagenesis, and as hydrothermal alteration of ferromagnesian minerals in igneous rocks (Deer *et al.*, 1992). In Nakhla chlorite is of hydrothermal origin, it is chemically very iron-rich (ca. 43 wt.% FeO; bright in SEM BSE images), and it is found as small lath-shaped crystallites (ca. 5μm in the long axis) inside a mixed-layer or nanocrystalline clay that is poorer in iron (probably sericite with ca. 30 wt% FeO; significantly darker in SEM BSE images). Altogether, the phyllosilicate structures are observed to be amoeboid in shape, and replace glass of feldspathic composition that is part of a sand-clock shaped melt inclusion of a large olivine grain. Apart from the glass, the original mineralogical make up of this twin melt inclusion is a Ti-rich magnetite crystal, two pyroxene crystals, and a hollow skeletal apatite crystal that is actually surrounded by the clay phases.

After the bolide shock event, hydrothermal fluids seem to have had access through the induced cracks, altering and leaching the igneous minerals, becoming increasingly rich in iron. In the current case, it seems that they were deposited along the cracks or altered the glass of the olivine melt pocket isovolumetrically (absence of hollow volumes). Moreover, they reacted with the rims of the clinopyroxene (clearly visible in high resolution FEG-SEM BSE images as bright nanoscale zones along the rims of the clinopyroxene where clays are in contact), and evidently, they cured a pre-existing crack of one of the clinopyroxene crystallites that are present in the inclusion. First temperature estimations using the chlorite as geothermometer result into temperatures that range between 360 °C (chlorite geothermometer of Cathelineau and Nieva, 1985) and about 460 °C (chlorite geothermometer of Cathelineau, 1988, and Jowett, 1991). This temperature range should be realistic, when the previous textural observations are also considered, which indicate that chlorite was formed in an earlier stage, when the hydrothermal fluids where still hot, while the hollow ovoid was deposited in the very last stages of hydrothermal alteration.

This discovery supports the scenarios proposed by Chatzitheodoridis *et al.* (2014), which suggest the existence of fast cooling hydrothermal fluids, which affected the sample in different degrees even in small distances, depending on the access of the fluids to the different locations. It is therefore concluded that in the recent history of Mars bolide impacts fractured the parent rock of Nakhla and induced aqueous hydrothermal fluids, creating niche environments in the subsurface of the planet, in the same way with habitable terrestrial environments (Pontefract *et al.*, 2014). The direct evidence from Nakhla and other martian meteorites, as well as that the detailed study of terrestrial analogue environments, has significant implications for astrobiology and for future missions.

References

1. Cathelineau, M. (1988) Cation site occupancy in chlorites and illites as a function of temperature. *Clay Miner.*, 23:471–485.

2. Cathelineau, M. and Nieva, D. (1985) A chlorite solid solution geothermometer. The Los Azures (Mexico) geothermal system. *Contrib. Mineral. Petrol.*, 91:235–244.

3. Chatzitheodoridis, E., Haigh, S., and Lyon, I. (2014) A Conspicuous Clay Ovoid in Nakhla: Evidence for Subsurface Hydrothermal Alteration on Mars with Implications for Astrobiology. *Astrobiology*, 14:651–693.

4. Deer, W.A., Howie, R.A., and Zussman, J. (1992) An Introduction to the Rock-Forming Minerals, 2nd ed., Pearson Prentice Hall, Upper Saddle River, NJ.

5. Jowett, E.C. (1991) Fitting iron and magnesium into the hydrothermal chlorite geothermometer. *GAC/MAC/SEG Joint Annual Meeting* (Toronto, May 27-29, 1991), Program with Abstracts 16:A62.

6. Pontefract, A., Osinski, G.R., Cockell, C.S., Moore, C.A., Moores, J.E., and Southam G. (2014) Impact-generated endolithic habitat within crystalline rocks of the Haughton Impact Structure, Devon Island, Canada. *Astrobiology*, 14:522–533.

24

Drastic Environmental Change and its Effects on the Habitability of the Terrestrial Planets of our Solar System

Dirk Schulze-Makuch, Alberto Fairen, and Louis Irwin

Based on our knowledge of the natural history of Earth, the effect of drastic environmental changes on a planet's biosphere can be attributed to three main factors: (1) the nature and time scale of change, (2) the composition of the biosphere prior to change, and (3) the nature of the environment following the change. Rapid and drastic environmental change has occurred frequently on Earth, posing a critical challenge to life. However, directional selection has overcome those challenges and driven life on our planet to ever increasing diversity and complexity. Mars and Venus have undergone even larger environmental changes, both from habitable conditions under which the origin of life (or transfer of life from Earth) seem plausible, to a dry and cold planet punctuated by wetter conditions, and a hyperthermic greenhouse, respectively. Given its planetary history, life on Mars could have retreated to a psychrophilic lifestyle in the deep subsurface or to environmental near-surface niches, such as hydrothermal regions and caves. Further, strong directional selection could have pushed putative Martian life to evolve alternating cycles between active and dormant forms, as well as the innovation of new traits adapted to challenging near-surface conditions (e.g., use of H_2O_2 or perchlorates as antifreeze compounds). Life in the subsurface or on the surface of Venus seems impossible today, but microorganisms may have adapted to thrive in the lower cloud layer, possibly using a biochemical strategy based on chemoautotrophic sulfur metabolism (e.g., analogous to the Photosystem I on Earth), and employing cycloocta sulfur for UV protection.

25

Preservation, stability and recovery of signatures of life from mineral matrixes

Susana Direito and Charles Cockell

UK Centre for Astrobiology, School of Physics and Astronomy, University of Edinburgh, Edinburgh EH9 3JZ, Midlothian, Scotland

The detection of signatures of life is fundamental to determine whether there is extinct or extant life beyond Earth. If life ever existed, for example on our neighbour planet Mars, it is most likely we will find vestiges of it on the subsurface where the extreme surface conditions have no detrimental effect. These signatures may be possibly found entrapped in mineral matrixes. However, the influence of mineral composition on biomarkers detection and preservation is not yet fully understood.

In order to investigate the potential persistence of organic or biormarker molecules in mineral matrixes and the preservation potential of certain minerals, the experimental evaporation-driven mineralization of organic molecules was performed. A selection of different minerals was used, including silica, gypsum, halite, calcite and phosphate-rich minerals. Different organic molecules are also considered in this study (DNA, proteins, polyamino acids and PAHs - Polycyclic Aromatic Hydrocarbons) since focusing on more than on type of organic molecule increases our chances to detect life. Preliminary results show differences between minerals, in particular for phosphate-rich.

The obtained results are relevant not only for aiding in life detection and in selecting sampling locations, for example on other planets such as Mars, but the results also provide guidelines on the persistence and preservation of certain organic molecules in modern or present day terrestrial environments.

26

UV, Microwave and Heat Shock Resistance in Manganese Requiring *Bacillus sp.* Strains Isolated From Manganese Mine in TURKEY

Ş. Orçun KALKAN

Ege University, Faculty of Science, Department Biology, Fundamental and Industrial Microbiology Izmir/ TURKEY 35100

Spores of *Bacillus sp*. are extremely resistant to a variety of harsh processes including heat, radiation and oxidizing agents. Recent evidence from studies of several biological systems has indicated that prevention of cell killing by agents like in particular desiccation, gamma irradiation, and UV radiation that can cause lethal damage by generation of reactive oxygen species (ROS). One of this agent protecting proteins against ROS is Mn^{+2} ($MnCl_2$) ions complexed with low molecular weight species amino acids, peptides or nucleosides. It has been suggested that Mn^{+2} complexes scavenge ROS in vivo, thus in effect increasing cell resistance to agents that kill cells through ROS generation. Although Mn^{+2} is most commonly associated with its role as a catalytic and/or structural protein cofactor, the majority of cellular Mn in radiation- resistant bacteria

This study suggests that *Bacillus sp*. cultures isolated from manganese mine to be more resistant against the processes mentioned above because they naturally contain more Mn in their cells than any others.

In this study, 16 bacteria isolated from 3 different samples (mine core, outside of ore and mine pulp) and they have identified by using microscopic and phenotypic methods. Also we are going to do 16S rRNA sequances and gamma irradiation experiment. Isolates were sporulated with no added $MnCl_2$ and up to 500 □M $MnCl_2$. The outcome spores were purified and loosely bound Mn removed, and spore Mn levels were found to vary 240- fold. Spores with elevated Mn levels had higher resistance (survival rate up to the %78) to UV radiation, 700 watt microwave, wet and dry heat but control group with no added $MnCl_2$ and native *Bacillus subtilis* and *B. cereus* cultures were significantly sensitive UV and wet heat.

27

Mineralogical characterization of spring deposits: the importance of the Dallol area (Ethiopia) in astrobiology

[1,2]CAVALAZZI B., [1]PALAZZO Q., [1]GASPAROTTO G., [2]AGANGI A., [1]BARBIERI R., [3]HAGOS M., [1]CAPACCIONI B., [3]KIROS K.

[1]*Università di Bologna, Italy*
[2]*University of Johannesburg, South Africa*
[3]*University of Mekelle, Ethiopia*

Contact email: barbara.cavalazzi@unibo.it

Today, Mars surface has harsh conditions for life to exist. However, the identification of a specific mineral assemblage (e.g. jarosite) provided a possible scenario for a past aqueous acidic Martian environment, and micro-niches where life could possibly exist despite the adverse conditions. The importance to study extreme terrestrial environments is the possibility to learn from these analogs about the possibilities of life on other planetary bodies. The Dallol hydrothermal area as suggested by this study could be considered, together with Rio Tinto, an excellent Mars analog due to the similarities in the mineralogy of the system with that reported by MER Opportunity Rover missions.

Dallol hydrothermal field is a sub-aerial (~120 m below *s.l.*), hot (average annual temperatures: 35°C) volcanic area located in the northern Danakil Depression in Ethiopia. Here, an intense hydrothermal activities affect a vast area of uplifted, thick salt deposits, and generate hot, acidic (pH < 1.0), Fe-rich brine and unique salt deposits that can potentially host life. Here, we present the results of a detailed mineralogical study conducted on samples collected from salt and sulphur deposit during a field campaign in 2013. Studied samples reveal the presence of halite (<90%), anhydrite, gypsum, sylvite, jarosite, sulphur, Fe-oxy/hydroxides, and scattered detrital materials.

28

WIND-ERODED SILICATE AS A SOURCE OF HYDROGEN PEROXIDE ON MARS.

E.N. Bak[1], J.P. Merrison[2], S. K. Jensen[3], P. Nørnberg[4] and K. Finster[1,2],

[1-4]Aarhus University, Denmark. [1]Department of Bioscience, [2]Department of Physics and Astronomy, [3]Department of Chemistry, [4]Department of Geoscience.

Introduction: Investigations of Mars as a potential habitat for past or present life depend on understanding the chemistry of the Martian soil as it affects the preservation of organic compounds and thus the risk of forward contamination as well as the suitability of organic compounds as biomarkers. The classical Gas Exchange Experiment and the Labeled Release Experiment conducted by the Viking Landers demonstrated that the Martian surface soil is oxidizing [1, 2]. However, the cause of the soil's oxidizing properties is uncertain [3]. The Martian surface material mainly consists of silicates [4] that due to wind erosion has a very fine grained texture. Based on the composition of the surface material and investigations showing that crushing of silicates can give rise to reactive oxygen species [5], we hypothesized that wind erosion of silicates can explain the reactivity of Martian soil.

Methods: We simulated wind-erosion of silicates by tumbling quartz sand in sealed quartz ampoules with defined atmospheres. The eroded sand was suspended in water and the hydrogen peroxide concentration was followed using a scopoletin/horseradish peroxidase assay.

Results: The simulated wind-erosion effectively eroded the sand over weeks of tumbling and we saw a clear correlation between an increase in surface area and the release of hydrogen peroxide. The production of hydrogen peroxide depended on the presence of atmospheric oxygen and was inhibited by atmospheric carbon dioxide. Nevertheless, taking into account the high surface area of Martian soil and the atmospheric oxygen and carbon dioxide content, wind-eroded silicate could result in the formation of at least 7 to 31 nmol hydrogen peroxide per cm^3 soil, which could explain the amount of $^{14}CO_2$ released in the Labelled Release Experiments [6]. Further, the heat-stability of eroded silicate as a source for hydrogen peroxide matches to the results obtained by the Viking Landers.

Discussion: Wind-eroded silicate as a potential source of hydrogen peroxide does not contradict previously proposed hypothesis for the cause of the reactivity of Martian soil. Wind-erosion of silicate could thus be one of several causes of the soil's reactivity.

As our experiments show, the globally distributed wind eroded silicate dust can lead to the production of hydrogen peroxide which might explain the reactivity of the Martian soil. The reactivity of eroded silicate could further affect the degradation of organic compounds on Mars, be a stress factor for past and present life as well as pose a danger to future Mars explorers.

[1] Levin G. V. and Straat P.A. (1977) *JGR, 82,* 4663-4667. [2] Oyama V. I. and Berdahl B. J. (1977) *JGR, 82,* 4669-4676. [3] Zent A. P. and McKay C. P. (1994) *Icarus, 108,* 146-157. [4] Bish D. L. et al. (2013) *Science, 341.* [5] Vallyathan V. et al. (1988) *Am Rev Respir Dis, 138,* 1213-1219. [6] Klein H. P. (1978*) Icarus, 34,* 666-674.

29

Structural studies of bacterial ice nucleation proteins and their relevance for atmospheric processes

Ling M[1,2,3], Santl Temkiv T[1,2], Finster K [1,2], Boesen T[3]

[1]*Aarhus University, Stellar Astrophysics Centre, Department of Physics and Astronomy, Aarhus, Denmark*
[2]*Aarhus University, Department of Bioloscience, Microbiology Section, Aarhus, Denmark*
[3]*Aarhus University, Department of Molecular Biology and Genetics, Aarhus, Denmark*

Microorganisms have been proposed to play a role in shaping the Earth's climate by acting as ice nuclei (IN), thus influencing the formation of clouds. This can have significant implications for the global distribution of clouds and precipitation, and consequently for Earth’s weather patterns and climate. Similar to Earth, exoplanetary atmospheres may provide information on the possible presence of life on those planets. In this fashion, atmospheric phenomena such as planetary albedo, which may be influenced by ice nucleation active (INA) bacteria, may serve as potential biosignatures.

However, before biologically induced atmospheric processes can be used as reliable biosignatures for life detection in other worlds, a thorough understanding of how and to what extend INA bacteria influence atmospheric phenomena on Earth is needed. Consequently, there is a need to determine the ice-nucleating property of living organisms by investigating the structure and properties of INA proteins (INP). Several bacterial species that have been found in the atmosphere produce INP. Situated on the cell-surface of bacteria, INPs have the capability of facilitating the formation of ice crystals in supercooled water by acting as an ice template [1] and inducing ice formation at temperatures much higher than mineral aerosols, which are generally considered the most abundant IN in the atmosphere. We will investigate the role of INA bacteria in cloud formation by answering the fundamental question: by which mechanism(s) do bacterial INPs facilitate ice crystal formation? This will be accomplished by elucidating the atomic structure of an INP.

Hitherto, different groups have presented INP models based on homology modeling efforts revealing an elongated, β helical protein and an ice binding mechanism [2][3]. However, little has been done experimentally to validate the models and to determine the tertiary structure of an INP. We aim at experimentally determine the structure of the highly conserved repeat domains of INPs, which may yield insights into their ice nucleation mechanism. Given their important function for bacterial ice nucleation, we will focus on the functional analysis and protein structure determination of individual INP domains. To study INP, we sequenced the INA gene from a bacterial strain designated *Pseudomonas* sp. R10.79 that was isolated from a rain sample. Additional functional analysis of INP from *Pseudomonas* sp. R10.79 will be continued using molecular biology techniques including molecular cloning, protein purification in combination with X-ray crystallography. In the long-term, we hope that our detailed studies of the molecular structure of INP will hold a key to finding life on other planets.

[1] Morris, C. E., Georgakopoulos, D. G., and Sands, D. C. (2004). Ice nucleation active bacteria and their potential role in precipitation. *J. Phys. IV*, 121, 87–103.

[2] Graether, S. P., and Jia, Z. (2001). Modeling Pseudomonas syringae ice-nucleation protein as a beta-helical protein. *Biophys. J.*, *80*(3), 1169–1173.

[3] Garnham, C. P., Campbell, R. L., Walker, V. K., & Davies, P. L. (2011). Novel dimeric β-helical model of an ice nucleation protein with bridged active sites. *BMC Structural Biology*, *11*(1), 36.

30

Ancient (PR_1) microorganism colonization of volcanic glasses

Astafieva M.M.

Paleontological Institute, Russian Academy of Sciences

Ancient Archaean and Paleoprotherozoic rocks are the model objects for investigation of astromaterials. Usually they are represented by deeply metamorphized volcanogenic and volcanogenic-sedimentary rocks. The bacterial-paleontological study of glassy matrix of Paleoproterozoic pillow lavas of Karelia (2.0 Ga) and their comparison with extant forms suggests that recent and ancient basaltic glasses of pillow lavas contain rather diverse microbial assemblages. It was also corroborated that microorganisms colonized the basalt glass of Early Precambrian underwater eruptions, as do extant microorganisms, colonizing modern volcanic glass.

The study of different portions of pillow lavas, in particular, their inter-pillow matrix, as well as marginal and central zones revealed significant differences in the distribution of microfossils. The main difference consists in the significantly more abundant and diverse complexes of microfossils in the inter-pillow matrix and their marginal parts as compared to pillow cores. The chemical composition of fossilized organisms in all cases corresponds to the chemical composition of the host rocks. This is consistent with in-situ burial of microorganisms. Thus, the studied complexes represent pseudomorphs that practically completely exclude the preservation of organic material. The distribution of microfossils in the pillow-lavas indicates that the most favorable conditions for development and blossoming of life existed in sediments lying immediately on the pillow surface. Precisely these sediments were lately transformed into inter-pillow matrix. The marginal parts of the pillow lavas at the contact with sediments also represented a sufficiently favorable medium for the development of microorganisms.

31

MARTIAN METABOLOMICS: DIFFERENTIATING TERRESTRIAL AND MARTIAN ORGANIC CARBON IN METEORITES

J. Gunn[1*], P. Ascough[1], D. Morrison[1], K. Burgess[2], C. Cockell[3], J. Faithfull[4], M. R. Lee[5], D. Mark[1], C. L. Smith[6].

[1]Scottish Universities Environmental Research Centre, Rankine Avenue, East Kilbride, [*] presenting author email: Jacqueline.Gunn@glasgow.ac.uk. [2]Glasgow Polyomics, University of Glasgow. [3]School of Physics and Astronomy, University of Edinburgh.[4] Hunterian Museum, University of Glasgow. [5]School of Geographical and Earth Sciences, University of Glasgow. [6] The Natural History Museum, London.

Obtaining a realistic picture of the structure and diversity of Martian carbon is the key to understanding the geological evolution of Mars and its carbon cycle. This also informs how we reconstruct the delivery of organic carbon to the terrestrial planets (e.g. Earth), and influences the search for non-terrestrial biotic/pre-biotic activity. Analysis of Martian meteorites is currently the most effective means to characterise Martian carbon, and has transformed our knowledge of the planet, confirming the presence of complex carbon chemistry [1]. A major limitation in using meteorites however, is differentiating Martian carbon from terrestrial contaminants.

We describe an on-going collaborative project aimed at addressing this problem by analysis of a suite of terrestrial analogue and Martian meteorite samples including Tissint, the most recent Martian fall. The overall aim is to produce a 4-dimensional map of organic carbon distribution in these samples by characterising both labile and non-labile carbon using untargeted metabolomic techniques to fingerprint terrestrial organic carbon inputs.

[1] Bada JL, Glavin DP, McDonald GD, Becker L. 1998. Science 279, 362–365.

32

Protenoid microsphere foremation in the thermal polycondensation of monoammonium malate

Mita Hajime*, Kouda Hikaru, Kanamaru Hiroshi, Nakai Takahiro, Hatae Kota, Turuyama Mami, and Kuwahar Ryusuke

Fukuoka Institute of Technology

mita@fit.ac.jp

Proteins are ones of the most important organic compounds in terrestrial living organisms. Amino acids widely distribute in the universe, since amino acids are detected in carbonaceous chondrites, and large numbers of simulated experiments. However, formation of polyamino acids is a relatively difficult in the prebiotic conditions. Although there are some reports of polyamino acid formation in the prebiotic condition, most of them are limited reaction for specific amino acids. One of the famous experiments of polyamino acid formation is thermal polycondensation of monoammonium malate. The product is called proteinoid, which is an imide form polyaspartic acid, anhydropolyaspartic acid. When proteinoid is disolved into hot water and cooled, globular structure called proteinoid microsphere is appered. In this study, we studied the properties of the proteinoid and microsphere by amino acids analyser, LC-MS, GPC, IR, DLS, and SEM. Relatively large molecular wieght of proteinoid was synthesized with higer temerature. In the proteinoid microspher, moleculra weight distribution was narrower than that of the thermally synthesized proteinoid. Size of the proteinoid microspheres depended on metal ion concentrations in the microsphere formation conditions. When too large microsphere (ca. > 2 micro metter) was formed with high concentration of metal ions, the microsphere was aggregated and precipitated.

33

Influence of volatiles on the composition of the surface and atmosphere of Mars

Maria I. Błęcka

Space Research Centre Polish Academy of Sciences, Bartycka 18a, 00-716 Warsaw Poland,
mib@cbk.waw.pl

Although Mars today is a dry, cold planet, it may once have been much warmer and wetter. The images of Mars clearly show the signatures of past bodies of standing water, where the accumulation of sedimentary deposits should have occurred. Understanding geochemical and degassing history of various volatiles is most important in examination the history of Martian climate and the surface of Mars.

The examples of interaction between the atmosphere, hydrosphere, and regolith of Mars and possible modification of Martian surface, geochemical cycles models connected with production of various minerals e.g. carbonates will be shortly reviewed. Some new information about the presence of carbonates on Mars and possible explanation of difficulties of spectral detection on the surface and in the atmosphere from orbits will be also presented. The comparison the results of simulations with observed spectra will be shown.

Acknowledgements: The work was supported by the grant: 2011/01/B/ST9/05442

34

Early evolution of genetic code inferred from extant mitochondrial genetic decoding system

Kimitsuna Watanabe[1,2] & Shin-ichi Yokobori[1]

[1]Laboratory of Extremophiles, Department of Applied Life Sciences, Tokyo University of Pharmacy and Life Sciences, Hachioji, Tokyo 192-0392, Japan, and [2]Department of Biotechnology, Graduate School of Agricultural and Life Sciences, The University of Tokyo, Bunkyo-ku, Tokyo 113-8657, Japan.

All extant organisms use same genetic code (standard genetic code) in general, suggesting that the standard genetic code was established before LUCA (or Commonote). How the standard genetic code was established is one of most important issues for the origin of life. The early translation systems prior to the establishment of standard genetic code would have been much simpler than modern translation system. For example, the posttranscriptional modification of RNA might have been absent in early translation system. We have studied the evolution of variation of mitochondrial genetic code and decoding system of mitochondrial tRNAs. In some metazoan mitochondrial decoding systems, it was found that unmodified anticodons of tRNA have the potential to basepair with cognate codons and retain flexibility at the wobble pair, suggesting that the early decoding system consisted of unmodified RNA prior to the emergence of RNA-modifying systems. We will summarize the basepairing rule between anticodons of tRNAs and codons in metazoan mitochondria. Then, we will present a possible early codon table that has been decoded by tRNAs without any posttranscriptional modifications.

35

CHEMICAL EVOLUTION: TOWARDS CREATION OF LONG UNSATURATED CARBON-NITROGEN CHAINS: HC_9N AND $C_{10}N_2$

Urszula Szczepaniak[a, *], Claudine Crépin[b], Michał Turowski[a], Thomas Custer[a], Michele Chevalier[b], Marcin Gronowski[a], Jean-Claude Guillemin[c], and Robert Kołos[a]

[a] Institute of Physical Chemistry, Polish Academy of Sciences, Kasprzaka 44, 01-224 Warsaw, POLAND, [b] Institut des Sciences Moléculaires d'Orsay, UMR 8214, CNRS, Université Paris-Sud, Orsay F-91405, FRANCE, [c] Institut des Sciences Chimiques de Rennes, 11 Avenue de Beaulieu, CS 50837, 35708 Rennes Cedex 7, FRANCE, [*]uszczepaniak@ichf.edu.pl

Cyanopolyynes (HC_nN) are important molecules among those of the established or potential astrochemical interest; species as large as $HC_{11}N$ have already been detected in space [1]. Their spectroscopy, however, is still rather poorly known, as the molecules are highly reactive and hard to obtain in a laboratory.

Under certain conditions, the coupling of these unsaturated carbon-backbone chains may create the longer members of the same or related (NC_nN) homologous series. The cryogenic matrix isolation technique is well suited for the investigation of such processes – molecules of interest are synthesized via the radiation-induced reactions between appropriate smaller precursors (here: HC_5N and C_4H_2), trapped as “impurities” within the crystal lattice of a frozen rare gas (here: krypton). Photochemical products, stable in this environment, can be subjected to spectroscopic investigations. The identification of products was based on electronic luminescence spectra, and was assisted with DFT calculations.

$$H\text{-}(CC)_2\text{-}H,\quad H\text{-}(CC)_2\text{-}CN \quad\rightarrow\quad H\text{-}(CC)_4\text{-}CN,\quad NC\text{-}(CC)_4\text{-}CN$$

This line of study can be useful for the description of processes taking place in chemically inert astrophysical ices.

The work was supported within the framework of the Polish NCN grant 2011/03/B/ST4/02763 and the Partenariat Hubert-Curien project Polonium 2012-2013. U. Szczepaniak is a beneficiary of the project “Scholarships for PhD students of Podlaskie Voivodeship”, co-financed by the European Social Fund, Polish Government and Podlaskie Voivodeship.

36

Investigating the rock weathering and carbon utilization capabilities of a microbial community isolated from Whitbian shale cliffs

T. Samuels[1], T. Stratford[2], D. Pybus[3] and C. Cockell[1]

1. UK Centre for Astrobiology, School of Physics and Astronomy, The University of Edinburgh
2. School of Engineering, The University of Edinburgh
3. Cleveland Potash Limited, Boulby, Yorkshire

Current models for cliff erosion have been shown to be inadequate in explaining erosive rates and patterns observed at cliffs on the Yorkshire coast. To determine the biological impact on the weathering of the Lower lias mudrock, a microbial community was isolated from the interior walls of a mine dug into the shale cliffs at Hole Wyke. As part of this investigation, the communities ability to enact geochemical and physical alterations to shale will be explored. In addition, the metabolic capabilities of the community to utilize different kerogen types (I, II, III and IV) and Allende carbonaceous chondrite material as a carbon source or an electron donor is being studied. Kerogenous organic material found in mudrocks and shales, macromolecular organic compounds that are both insoluble and non-hydrolyzable, form the largest pool of organic carbon on Earth. Although differing in origin, the chemical and reactive properties of these two materials are similar. In this poster, evidence for microbial colonization of shale and kerogen-rich rock surfaces and initial results indicating rock-dependant growth is presented. Future work to demonstrate direct uptake of kerogenous and kerogenous-like carbon to form biological material, and the investigation into the metabolomic response of kerogen-degradation in this microbial community, is explored.

37

Pressurized Martian-like pure CO_2 atmosphere is highly usable for the culturing of cyanobacteria

Gayathri Murukesan[1], Hannu Leino[1], Pirkko Mäenpää[1], Kurt Ståhle[1], Wuttinun Raksajit[2], Harry Lehto[3], Kirsi Lehto[1]

Dept. of Biochemistry, Laboratory of Molecular Plant Biology, University of Turku, Finland.
Faculty of Veterinary Technology, Kasetsart University, Bangkok, Thailand
Tuorla Observatory, Dept. of Physics and Astronomy, University of Turku, Finland

Surviving of the crews during future missions to Mars will depend on reliable and adequate supplies of essential life support materials, i.e. oxygen, food, clean water, and fuel. The most economical and sustainable (and in long term, the only viable) way to provide these supplies on Martian bases would be via bio-regenerative systems, by utilizing local resources (In Situ Resourse Utilization, ISRU) to drive oxygenic photosynthesis. Photosynthesis requires light for energy source, liquid water, carbon dioxide, nitrogen and mineral nutrients (P, K, Mg, Mn, Fe and micronutrients). Mineral nutrients would be available, via (bio)leaching, from the basalt-like Martian regolith. The atmosphere contains carbon dioxide and molecular nitrogen, although their ratios are very different from their occurrence in terrestrial atmosphere. The local conditions are too harsh as such for any photosynthetic organism, but with some level of containment they could support the growth of different cyanobacteria which, again, could serve as pioneer species to produce life substrates for higher organisms. Still, the growth and metabolism of even these sturdy photosynthetic species might be strongly affected by different features of the Martian environment. Here we show that modified, Martian-like atmospheric composition (nearly to 100 % CO2, with limited nitrogen supply) under adequate pressure (about 50 mbar) to maintain liquid water, supports strong cellular growth, but also induces very strong nitrogen fixation, bio-hydrogen production, and significantly reduces the protein content and enhances the total sugar content, as calculated per unit of dry weight.

38

Potentials of Thermophiles for improvement of Agriculture in Rajasthan-India

Dr.Debajyoti Bose*

Reader & Head, Department of Biological Sciences, Yobe State University, KM 7, Gujba Road, P.M.B. 1144, Damaturu, Yobe State, Nigeria

Contact No. :+234-8189491584 e-mail ID: debajyotibose@gmail.com

Thermophillic bacteria was screened from the soils of Jaipur, Jodhpur & Jaisalmer districts of Rajasthan, India. These bacteria showed a temperature range of 40˚C - 78˚C for their growth. The bacteria isolated from Jaisalmer soil showed amylase positive reaction, whereas from Japiur & Jodhpur soil, negative result at a specific temperature. Bacteria isolated from soils of Jaipur, Jodhpur & Jaisalmer showed negative results for catalase test. Bacteria isolated from Jaipur , Jodhpur & Jaisalmer soil showed gram negative short rod shapes. The bacteria isolated from Jaipur & Jodhpur soil showed positive result for endospore staining but that from Jaisalmer, showed negative result. Bacteria isolated from the soils of Jodhpur and Jaisalmer are showed negative results for Indole and Methyl Red test, where as a positive result for Voges-Proskauer test. Bacteria isolated from the soil of Jaipur showed negative results for Indole and Voges-Proskauer test, where as a positive result for Methyl Red test. All the thermophilic bacteria isolated from the above mentioned districts of Rajasthan showed good results for acid and alkaline phosphatase enzyme production & some with amylases. Both acid and alkaline phosphatase activity was observed in all the soil samples during the experiment, among which highest in case of Jodhpur soil. The acid phosphatase and alkaline phosphatase activity was 11.7x10-5µ mol PNP sec-1g-1 and 8.48x10-5µ mol PNP sec-1g-1 respectively for Jodhpur soil sample. This signifies the beneficial effect of isolated phosphatase producing thermophilic bacteria on soils of mentioned districts of Rajasthan, India towards betterment of agriculture.

Key Words: Thermophillic bacteria, Jaipur, Jodhpur, Jaisalmer, Acid phosphatise, Alkaline phosphatise, Amylases.

*Author for correspondence

39

Biosignatures of early life in >3.8Ga Banded Iron Formations?

Matthew S Dodd and Dominic Papineau

London Centre for Nanotechnology and Department of Earth Sciences, University College London

Early Earth was an alien world in comparison to today. Study of early life on Earth will help the search for extra-terrestrial life by providing knowledge on primordial habitats and possible chemical functions; it will also help choose areas of interest on other planets and provide an analytical approach to address the big question 'Are we alone?'. It is essential to keep an open mind as to what chemistry is involved and to critically evaluate data to rule out all nonbiological explanations. However, expected common features will include the necessity for water (aqueous habitable environment) and a chemical composition dominated by Carbon. Graphitic carbon depleted in 13C in Eoarchean Banded Iron Formations (BIFs) has been suggested as an indicator of life (Schidlowski et al., 1979; Rosing, 1999; Ohtomo et al., 2013).

This study builds on previous work, by reporting new analyses of graphitic carbon in BIFs from the Eoarchean (possibly Hadean) Nuvvuagittuq Supracrustal Belt (NSB). Recent micro-Raman analyses of NSB jaspilites reveals the presence of phosphate minerals associated with carbonate, which might suggest past decarbonation reactions. Phosphate itself is one of the elements deemed critical for biological activity (nucleic acids, metabolism, signal transduction, and membranes), which makes these minerals particularly interesting as potential biosignatures.

Further work will look at the chemistry of fluid inclusions associated with apatite and other phosphate minerals in the BIFs. Also, micro-fabrication and extraction of graphitic carbon via micro-manipulation, will allow for nano-scale petrographic and geochemical analysis of carbon in BIFs.

References

Ohtomo, Y., Kakegawa, T., Ishida, A., Nagase, T., & Rosing, M. T. (2013). Evidence for biogenic graphite in early Archaean. *Nature Geoscience* , 25-28.

Rosing, M. T. (1999). 13C-Depleted Carbon Microparticles in >3700-Ma Sea-Floor Sedimentary Rocks from West Greenland. *Science* , 674-676.

Schidlowski, M., Appel, P. W., Eichmann, R., & Junge, C. E. (1979). Carbon isotope geochemistry of the 3.7x10^9 - yr-old Isua sediments, West Greenland: implications for the Archean carbon and oxygen cycles . *Geochemica et Cosmochimica*, 189-199.

40

Morphological features of microorganisms dwelling in an active low-temperature serpentinization site, Cabeço de Vide, Portugal: a possible analogue to early Mars

A.Z. Miller [1,2], S. Suzuki [3], J.M. Marques [1*], C. Rocha [1], G. Etiope [4], S. Vance [5] & L. Christensen [5],

[1] *CEPGIST/CERENA, Instituto Superior Técnico, Universidade de Lisboa, Portugal*
[2] *Instituto de Recursos Naturales y Agrobiologia de Sevilla (IRNAS-CSIC), Spain*
[3] *Department of Microbial and Environmental Genomics, J. Craig Venter Institute, USA*
[4] *Istituto Nazionale di Geofisica e Vulcanologia, Sezione Roma 2, Italy*
[5] *Jet Propulsion Laboratory, California Institute of Technology, USA*

Microorganisms inhabit nearly every conceivable niche on Earth where water is present, including subterrestrial hydromineral sites. Serpentinizing ecosystems have been identified as potential analogues for the origin of life on Earth and Mars, increasing the interest in their study. The mineral waters from Cabeço de Vide (CdV) are ascribed with outcropping ultramafic plutonic rocks comprising peridotites, serpentinized peridotites to serpentinites. These waters present very alkaline pH values (pH ≈ 11.5) and a Na-Cl/Ca-OH *facies* as the result of present-day serpentinization at depth. Methane isotopic composition (-24.4 $^{o}/_{oo}$ < δ^{13}C-CH_4 < -16.5 $^{o}/_{oo}$ and -285 $^{o}/_{oo}$ < δ^{2}H-CH_4 < -281 $^{o}/_{oo}$) falls in the range of typical abiotic gas found in other serpentinizing sites, and the lack of H_2 could be attributed to its consumption by CO_2 hydrogenation to produce CH_4. Microbial samples were collected from CdV mineral waters by in-line filtration. Subsequently, the filters were sputter coated with a Cr film and observed under Field Emission Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy. Coccoid and rod-shaped cells (≈ 1 µm) were observed infrequently, while smaller microbial cell-like structures (≈ 0.1-0.2 µm) were found forming clusters. We are presently seeking to understand whether these cell-like structures are actually life or just calcifying nanoparticles, since small sizes of microbes may have some advantages to thrive in this extreme environment. Small microorganisms were observed abundantly in other serpentinizing site, The Cedars, in Cazadero USA. Further molecular biology investigations, including metagenomic analyses, are underway to begin understanding life in this archetypal extreme environment.

Corresponding author

Centro de Petrologia e Geoquímica

Instituto Superior Técnico, Universidade de Lisboa

Av. Rovisco Pais, 1049-001 Lisboa

Portugal

jose.marques@ist.utl.pt

41

ALTERNATIVE BIOCHEMISTRY AND SPREADING OF EXTRATERRESTRIAL LIFE

K.B.Shumaev, A.F.Topunov

Bach Institute of Biochemistry, Moscow, Russia; e-mail:aftopunov@yandex.ru

New data on Solar system and exoplanets dramatically increased interest to extraterrestrial life. The questions is: how 'arterial' is the variant of metabolism dominated on the Earth and how possible are other ways of biosphere evolution? Life with alternative biochemistry could be discussed using metabolic diversity among Earth organisms. Even evolution of the Earth life resulted in 'extreme' ecosystems (i.e. 'Black smokers' and methane seeps).

The following biochemical systems are necessary: 1. self-replicating molecules; 2. energy metabolism with red-ox reactive compounds; 3. protective systems against environmental factors and reactive metabolites. Their co-evolution is the general term for existence of life.

At some conditions alternate replicators (not based on DNA and RNA) can be preferable: non-canonical base pairs or other sugars (instead of ribose or desoxyribose) can be used. Accessibility of microelements can be additional factor influencing the mainstream of extraterrestrial biocenoses.

Metabolism of the majority of Earth organisms is based on oxidation of organic compounds with oxygen. However existence of biospheres with domination of anaerobic ecosystems is possible. Compounds containing hexavalent sulphur and pentavalent nitrogen can be effective substitution for molecular oxygen. Products of their reduction can be reoxidased at anoxygenic photosynthesis or hemosynthesis. Preference of aerobic or anaerobic metabolism can affect evolution of protective systems, especially antioxidant ones.

Alternative biochemistry can significantly extend zone of the planet inhabitance. Thus amount of planets suitable for life could be larger than it is usually supposed.

42

DETECTING LIFE IN OTHER PLANETS: THE IN SITU SEARCH USING BIOELECTROCHEMICAL SYSTEMS AS BIOSENSORS FOR METABOLISM DETECTION

Abrevaya, Ximena C.[1]; Figueredo, Federico[2]; Saavedra Olaya, Albert U[2].; Cortón, Eduardo[2]

[1]*Instituto de Astronomía y Física del Espacio – IAFE, UBA-CONICET. Ciudad Universitaria, Buenos Aires, Argentina. abrevaya@iafe.uba.ar*
[2]*Departamento de Química Biológica, FCEyN – UBA and IQUIBICEN –CONICET. Ciudad Universitaria, Buenos Aires, Argentina.*

In a previous work (Abrevaya et al., Astrobiology 10: 965-971, 2010) we explored the potential of biolectrochemical systems (BES), in particular Microbial Fuel Cells (MFCs), to be used as *in situ* life detectors. In particular, we showed that MFCs used as sensors could allow the detection of microbial life based on metabolism, which is a common signature of life as we know it. We previously tested that this method allowed the detection of heterotrophic microorganisms from the three domains of life: bacteria, archaea and eukarya. In the present work we extend the capability of this method for the detection of other kind of metabolisms, specifically phototrophic and chemolithotrophic ones. As we showed in our previous work, our results indicate that the electrical response of these BES, using samples containing live microorganisms, dead microorganisms and culture medium without cells, were different, showing that much higher values were achieved when live microorganisms (and therefore metabolism) were present. Moreover, we demonstrated that it is possible to use these sensors to distinguish the kind of metabolism present in the sample, by using different configurations of MFCs. Therefore, we propose that these BES could be employed for the *in situ* detection of life, in future planetary exploration missions, presenting several advantages over the past and current methods proposed to reach this goal.

43

An eye on biomolecules spectral fingerprints: BEEST and FRACS

K.S.F. Fornazier [1], E.Janot-Pacheco [1], M. Rachid [1], Ph. Bendjoya [2], M. Adrian-Scotto [3], A. Domiciando de Souza [2], G. Niccolini [2], C. Lage [4]

[1] *Institute of Astronomy and Geophysics, São Paulo University, Brazil*
[2] *Department of Astrophysics, University of Nice, France*
[3] *Department of Chemistry, University of Nice, France*
[4] *Carlos Chagas Filho Institute of Biophysics, Rio de Janeiro Federal University, Brazil*

The present work is part of a project called **BEEST** - Biomolecules on Earth and Exoplanets through Spectroscopic Transitions - whose goal is the search for molecular signs of life on Earth and other planets. For this purpose, we analysed transitions in complex organic molecules related to Earth's living biosphere (such as nucleobases) and compare them to those found in spectral data from ISM targets.

The idea behind this is to consider bands observed in the ISM not only as a transition of a simple molecule/chemical bond but mainly a transition belonging to a more complex molecule. Our work consists on improving the analytical approach to screen for complex biomolecules by spotting peaks seen together in the same spectrum and check if they could be due to transitions of complex structures, as e.g. whole-ring vibrations.

Besides that, we are improving the **FRACS** code (Fast Ray-Tracing Algorithm for Circumstellar Structures) in order to include line spectra of complex molecules (such as CO and PAH) and those observed in circumstellar disks around young stars.

The improvement in the **FRACS** code will be very useful in the future to interpret data from **MATISSE** and **ALMA** interferometers.

44

The University of Hohenheim's Master's Programme in Earth System Science: An Opportunity to Specialize in Astrobiology

Henry Strasdeit

Department of Bioinorganic Chemistry, Institute of Chemistry, University of Hohenheim, 70599 Stuttgart, Germany
(henry.strasdeit@uni-hohenheim.de)

Many students of classical subjects such as biology, chemistry or astronomy at some point become interested in the fundamental questions dealt with by astrobiology. Some of them even become inspired to seek a career as an astrobiologist. The Master's programme Earth System Science (ESS) allows students to specialize in astrobiology. ESS is a 4-semester interdisciplinary programme at the University of Hohenheim in Stuttgart, Germany. ESS is research oriented. The language of instruction is English. Up to 20 students are admitted annually. ESS focuses mainly on the understanding and the simulation of Earth system components, such as the regional climate, land use and land management. However, from the second semester on, students can start specializing in astrobiology by attending the relevant courses:

► Lectures "Introduction to Astrobiology" and "Key Experiments in Astrobiology"
► Literature seminar on astrobiology
► Lecture "Chemical Evolution"
► Practical laboratory course "Chemical Evolution"
► Field excursion to the Ries crater, a relatively well-preserved 15 million year old, 24-kmwide impact structure 100 km east of Stuttgart.

The Master's thesis can be chosen from the topics "biosignatures" and "chemical evolution" (at Hohenheim) or other astrobiological topics (in cooperation with external institutions). The degree awarded is "Master of Science" (M. Sc.). Further details about the astrobiology branch within the ESS programme will be presented at the Workshop.

45

Rock geochemistry drives stress and starvation responses in the bacterial proteome

Casey Bryce[1], Sarah Martin[2], Thierry Le Bihan[2], Timothy Bush[3], Bryan Spears[4], Alanna Moore[4], Jesse Harrison[1], Natalie Leys[5], Bo Byloos[5] and Charles Cockell[1]

[1]UK Centre for Astrobiology, School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom
[2]Centre for Synthetic and Systems Biology, Institute of Structural and Molecular Biology, University of Edinburgh, Edinburgh, United Kingdom
[3]Condensed Matter and Complex Systems Group, School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom
[4]Centre for Ecology and Hydrology, Bush Estate, Edinburgh, UK
[5]Molecular and Cellular Biology, Belgian Nuclear Research Center SCK.CEN, Mol, Belgium[5]

The interaction between microbes and rock surfaces has been important throughout Earth's history and the alteration of rocks by microbes to obtain bioessential elements is well characterised. However, very little is known about the molecular adaptations microorganisms require to live in rock environments. We hypothesised that as well as providing nutrients for growth, rocks might also induce a variety of stresses caused by the complex geochemistry of the rock itself. To test this we used quantitative label-free proteomics to explore the molecular adaptations used by a microorganism (*Cupriavidus metallidurans* CH34) in the presence of volcanic rock. We show that the addition of the rock acts to satisfy some elemental requirements, improving growth in both magnesium and iron limited media. However the rocks themselves introduce new stresses via chemical changes associated with elemental leaching and surface adsorption effects. An example of this is the loss of bioavailable phosphorus and subsequent up-regulation of phosphate scavenging proteins. The initial limitation of an element (Fe or Mg) resulted in less than 15% difference in protein expression profiles showing that individual element starvation did not dominate the proteome response. Our results reveal that despite the provision of some elements, rock geochemistry drives complex metabolic reorganisation within rock-dwelling organisms and that these are substrate specific. Furthermore, the rock environment is shown to expose organisms to multiple simultaneous stresses, which requires rock-dwelling microorganisms to be able to tightly regulate cellular processes at the protein level.

46

Radiometrically calibrated hyperspectral photoluminescence imaging

R. E. Cross,[1] M.Gunn,[1] D. P. Langstaff,[1]D. P. Barnes[1] and D. A. Evans[1]

[1]*Institute of Mathematics, Physics and Computer Science, Aberystwyth University, Aberystwyth SY23 3BZ*

The hyperspectral luminescence microscope, HeLIOS (Hyperspectral Luminescence Imaging for Optical Spectroscopy), builds on previous instrumentation[1,2] and hyperspectral imaging[3,4] development in Aberystwyth. HeLIOS has received full radiometric calibration, traceable to a National Institute of Standards and Technology (NIST) calibrated source, providing data in physical units as opposed to arbitrary luminescence intensity, allowing direct comparisons and quantifications not previously possible.

HeLIOS is currently employed in a diverse range of interdisciplinary research including Material Physics, Computer Science, Astrobiology and Earth Sciences. Here we demonstrate its application to the study of spatially-resolved light emission in diamond and Mars analogue mineral samples in hyperspectral imaging mode. This application has allowed us to spatially correlate luminescence emission to reveal features in defect states and chemical compositions. Experiments for determining optimum excitation energies, intensities, temperature effects and the building of a Mars analogue reference spectral library are currently underway to support future planetary investigation of life via luminescence.

References

1. Poolton, N. R. J., Towlson, B. M., Hamilton, B. & Evans, D. A. *Nucl. Instruments Methods Phys. Res. Sect. B Beam Interact. with Mater. Atoms* **246,** 445–451 (2006).

2. Evans, D. A., Vearey-Roberts, A. R. & Poolton, N. R. J. *Appl. Phys. Lett.* **89,** 161107 (2006).

3. Cousins, C. R. *et al. Planet. Space Sci.* **71,** 80–100 (2012).

4. Barnes, D. *et al. ASTRA* (2011).

47

Properties of the Martian magnetic field in the context of a possible Mars exploration.

Erdmann Weronika & Kaczmarek Łukasz

Department of Animal Taxonomy and Ecology, Faculty of Biology, Adam Mickiewicz University in Poznań, Umultowska 89, 61-614, Poznań, Poland,

emails: *kaczmar@amu.edu.pl*, *weronika@erdmann.pl*

In recent years, more and more talk of manned flight to Mars. A visions of the colonization of the red planet become more real. Although many different factors are taken into account in these plans, a structure of the Mars magnetic field is often neglected.

It is well known that magnetic field of Mars is different from the geomagnetic field. It is not a dipole field, but is divided into a number of local fields. Probably, such magnetic field does not provide protection from the solar wind and cosmic rays. It means that the surface of Mars is exposed to much higher doses of cosmic radiation than the surface of Earth. Additionally, Martian magnetic field is much weaker than the Earth's field, which means that potential organisms sent to Mars will be exposed to hipomagnetic conditions.

Meanwhile, numerous studies have shown that the geomagnetic field not only protects the Earth and its biosphere, but also this that the Earth organisms have been adapted to this type of magnetic field. This is reflected in the functioning of cells, tissues, organs and entire organisms and the hipomagnetic conditions on Mars will have a negative impact on their functioning.

48

A Thermal Evolution Model of the Earth Including the Biosphere, Continental Growth and Mantle Hydration

D. Höning and T. Spohn

German Aerospace Center (DLR), Institute of Planetary Research, Berlin, Germany

By harvesting solar energy and converting it to chemical energy, photosynthetic life plays an important role in the energy budget of Earth. This leads to alterations of chemical reservoirs eventually affecting the Earth's interior. Recent studies have suggested that bioactivity may have caused a change in the redox-state of the mantle and provided a path for the formation of continents. We present a model including (i) parameterized thermal evolution, (ii) continental growth and destruction, and (iii) mantle water regassing and outgassing. The biosphere enters our model through an enhanced production rate of clay-rich sediments which eventually are subducted. These sediments are assumed to (i) carry water to depth bound in stable mineral phases and (ii) have the potential to suppress shallow dewatering of the underlying sediments and crust due to their low permeability. We gauge our model to present day Earth and simulate the evolution of an abiotic Earth using a reduced sedimentation rate. Our results suggest that the origin and evolution of life could have stabilized the large continental surface area of the Earth and its wet mantle, leading to the relatively low mantle viscosity we observe at present. Without photosynthetic life on our planet, the Earth would be geodynamical less active due to a dryer mantle, and would have a smaller fraction of continental coverage than observed today.

49

D-amino acids: constraint on habitability?

Sophie L Nixon[1], Charles S Cockell[1]

(1) *UK Centre for Astrobiology, University of Edinburgh, Edinburgh, UK*.

Mars hosts numerous ferric iron-bearing minerals, many of which formed under more habitable conditions than present day. As such, microbial iron reduction (MIR) represents one of the most plausible microbial metabolisms to operate on Mars, past and present. On Earth, iron-reducers couple iron reduction to the oxidation of organic compounds. Despite no unambiguous detection of organic compounds on Mars to date, meteoritic organics are expected to reside in the subsurface, originating from in-fall of carbonaceous chondrites throughout Martian history. These meteorites contain organic compounds known to support MIR, in addition to nonproteinogenic amino acids which are either rare or non-existent on Earth, which have not been tested as electron donors for MIR. Furthermore, chiral amino acids are present in racemic form, unlike on Earth where life has selected for L-amino acids only. Whilst D- amino acids are known to inhibit growth of aerobic microorganisms, this remains to be tested on anaerobic microorganisms using nonproteinogenic amino acids.

Results are presented from experiments testing the ability of iron-reducing microorganisms to use nonproteinogenic amino acids as electron donors for MIR. The inhibitory effect of chiral compounds was also tested. Of six compounds tested, one supported MIR. Furthermore, D-amino acids inhibited MIR in all strains at concentrations relevant to meteorite accretion rates onto the surface of Mars over geologic time. The likely mechanisms of inhibition and implications for Mars habitability are discussed.

50

The evolutionary potential of higher plants

Björn Huwe[a], Dr. Jean-Pierre de Vera[b], Prof. Dr. Jasmin Joshi[a]

[a]Universität Potsdam, Germany; [b]German Aerospace Center (DLR) in Berlin

Might it be possible that life from earth can adapt on earth to such extreme environmental conditions that they can survive a transport threw space to our next neighbor - the Mars? And when it reaches the Mars surface, alive, could it find a niche to grow?
To answer this question we investigate plants from one of the oldest terrestrial plant-groups, the mosses. From pretests of the BIOMEX-project (Biology and Mars Experiment) we could see that the moss Grimmia sessitiana can survive simulated space conditions like vacuum, extreme temperatures, UV radiation and desiccation as well as a Mars-like atmosphere. In July 2014 the moss and other organisms of the BIOMEX-Project were send to the International Space Station (ISS) for a one and a half year of exposure on the EXPOSE-R2 platform.

51

Mineralogical content, sulfur isotopic composition and carbon, nitrogen and sulfur analysis of Rio Tinto soils: Implications for the detection of biomarkers on Mars

Renato dos Santos[1], Chengxiang Li[2], Huifang Xu[2], Andreas Elsaesser[3], Esther Velasco[4], Roel van Elsas[4], Susana O.L. Direito[4,5], Joost Aerts[4], Gareth Davies[4], Wilfred F.M. Röling [4], Felipe Gómez[6], Bernard H. Foing[4,7], Pascale Ehrenfreund[3,8], Zita Martins[1]

1. Imperial College London, UK
2. University of Wisconsin, USA
3. Leiden University, The Netherlands
4. VU University Amsterdam, The Netherlands
5. University of Edinburgh, UK
6. Centro de Astrobiologia, Spain
7. ESA/ ESTEC, The Netherlands
8. Space Policy Institute, George Washington University, USA

The Rio Tinto area (in Spain) has been identified as an analog environment for Mars. We determined the mineralogical composition, sulfur isotopic composition and carbon, nitrogen and sulfur (CNS) profile of ten Rio Tinto samples collected during the CAREX field trip. Jarosite, quartz, pyrite, barite, hematite, goethite, illite, montmorillonite and K-feldspar were detected by X-ray diffraction. Sulfur isotopic measurements show that all samples are enriched in ^{34}S, supporting a volcanic origin and/or formation through hydrothermal sulfate reduction from coeval seawater. C/N ratios are used to determine the origin of the organic matter in the soils. Our data displays carbon/nitrogen ratios >9, suggesting an environment with poor protein content and/or dominated by terrestrial biomass. Our results show that Rio Tinto samples may contribute to a better understanding of the formation of Martian outcrops under acidic conditions, and to select the best target locations for future life detection missions on Mars.

52

Survival and viability of cells from iron depositing bacterial strains in pretests for the EXPOSE-R2-Experiment

Nina Feyh[1], Jean-Pierre de Vera[2], Ulrich Szewzyk[1]

[1]*Environmental Microbiology, Institute of Environmental Technology, TU Berlin,*

[2]*Institute of Planetary Research, DLR, German Aerospace Centre Berlin, Berlin, Germany*

Five environmental isolates (*Pseudomonas* sp. BS1, *Hyphomonas* sp. BS2, *Tetrasphaera* sp. FL1, *Pedomicrobium* sp. FL6 and *Leptothrix* sp. OT_B_406) were chosen for EXPOSE-R2 including pretests (EVT1/2, SVT) due to their ability to form Fe(III)-oxyhydroxide-containing biofilms as observed for natural communities of iron depositing bacteria.

Samples were produced by drying iron-containing cell aggregates on Mars regolith simulant mixtures (S-/P-MRS) (Böttger et al., 2012). Different Mars- and Space-relevant treatments were applied during EVT1/2 and SVT: artificial atmosphere, vacuum, UV-C irradiation and temperatures from -25 °C to 60 °C. Viability of cells was determined afterwards by recultivation and Fluorescence in-situ hybridization (FISH). In order to estimate membrane integrity, cell staining was applied as standalone-method and in combination with subsequent qPCR (PMA-qPCR) (Nocker et al., 2008).

Strains FL1 and FL6 were found to be recultivable from most of the samples. FISH-positive cells were detected in all sample types. PMA-qPCR was found to be superior to classic LIVE-DEAD staining due to being more sensitive. Culture independent techniques like FISH and qPCR can help to make more precise estimates about survival of microorganisms by detecting viable but not culturable cells.

Böttger et al. (2012), Planet Space Sci, 60: 356 - 362

Nocker et al. (2006), J Microbiol Methods, 67: 310 - 320

53

Tolerance of Seeds for Low Pressure and Thermal Cycle Environment

Hirofumi Hashimoto

Institute of Space and Astronautical Sciences, Japan Aerospace Exploration Agency, Sagamihara, Japan

In order to study the survival possibility of life in extraterritorial environment, tolerance of plant seeds for low pressure and thermal cycle environment was investigated. At first, seeds were exposed to vacuum environment at ~10^{-7} torr during the four weeks. After the vacuum exposure, germination rates of these seeds were almost the same as germination rates of control. In many species of seeds, the weight reduction of the seed was the same as the amount of water contained. These seeds have been very dry after the vacuum exposure. Secondly, thermal cycle test which was simulated for hard temperature change in earth orbit was conducted for seeds. Temperature was controlled with a cryostat and a heater that maximum was 100 C, minimum -80 C, and period 90 minutes in a vacuum vessel. The exposure experiments were operated in terms of 6 days and 60 days. After the exposure experiment, the survival rate was measured by the germination rate. Germination rates of seeds in exposure duration of 60 days were so lower than those of 6 days. These are estimated at further decreasing in long term of one year. In conclusion, seeds are very strong in low pressure environment but weak in thermal cycle environment.

54

Lichen resistance to extraterrestrial conditions: Viability, ultrastructure and algal growth

Annette Brandt[1], Jean-Pierre de Vera[2], Elke Rabbow[3], Silvano Onofri[4] & Sieglinde Ott[1]

[1]*Institute of Botany, Heinrich-Heine University , Düsseldorf*
[2]*Institute of Planetary Research , DLR, Berlin*
[3]*Institute of Aerospace Medicine, Radiation Biology Department, DLR, Köln*
[4]*Università degli Studi della Tuscia, Viterbo*

In the Lichen and Fungi Experiment (LIFE) the lichen *Xanthoria elegans* demonstrated considerable resistance to space and simulated Mars-analogue conditions being exposed on the International Space Station. This first European long-term exposure (559 days) of eukaryotic organisms tested their ability to cope with the combined hostile conditions of space and to cope with Mars-analogue atmosphere and insolation.
The samples showed remarkable resistance to the applied conditions, due to symbiotic features and adaptations. The algae resumed photosynthetic activity and both symbionts (photo-/mycobiont) showed high rates of metabolic activity (LIVE/DEAD staining). The results indicated 50 to 80% active algal cells and 60 to 90% active fungal hyphae.
Preliminary simulation studies focussed on viability after UV-radiation considering the protective effect of e.g. secondary lichen compounds. The present study investigated the cellular structural resistance of the anhydrobiotic lichen *X. elegans* after 1.5 years in space. The ultrastructure of the photobiont has been analysed, considering bio-membrane integrity, thylakoid-membranes, symbiotic interfaces and signs of structural damage after irradiation and vacuum effect. The current study focusses on the results obtained by culture experiments, demonstrating the algal growth capacity of the samples of *X. elegans* after being exposed 1.5 years in space.

55

MASE- Mars analogues for space exploration

Alexandra Perras[1], Maximilian Epple[1], Christine Moissl-Eichinger[1] and the MASE Team

[1] *Institute for Microbiology and Archaea Center, University of Regensburg, Regensburg*

Is life out there? This question has engrossed the human mankind for a long time. In order to assess the habitability of Mars, which is (or has been) the most Earth-like planet in our Solar System, the first step is to investigate microorganisms thriving in terrestrial biotopes with Mars-similar conditions and comparable multi-stresses. The MASE (Mars analogues for space exploration) consortium is a team of researchers from all over Europe, combining a broad spectrum of interdisciplinary expertise. Each research team is assigned to special task. Five major sampling sites (cold sulfur springs in Germany, Boulby mine in England, cold acidic lake in Iceland, Rio Tinto in Spain, permafrost samples from Svaldbard) were chosen with the major goal to cultivate and characterize novel anaerobic microorganisms which are specifically adapted to harsh conditions. A defined basic medium (the “MASE medium”) has been designed for isolation, enrichment and cultivation of anaerobic microorganisms with certain metabolic capabilities (e.g. sulfate reducers, methanogens, iron oxidizers/reducers); in this step the first collection of anaerobic microorganisms inhabitating Mars-like sites will be established. Secondly, cultivated microbes will be exposed to irradiation in combination with other environmental stressors relevant for Mars to gain insights into the limits for life. Finally, selected isolates will be fossilized and analyzed using certain life detection systems. This system could be directly applied on detecting life signatures on Mars.