The FRS-FNRS Contact Group
“Astrobiology: from stars and planets to extreme life”,
the EOS ET-HOME project
& the UR Astrobiology

are pleased to invite you on

Wednesday December 18th 2019
Building B18, Room R125, Campus du Sart-Tilman, ULiège
14 allée du 6 Août, quartier AGORA, 4000 Liège

Invited speakers

FRANCIS ALBAREDE (Ecole Normale Supérieure, Lyon, France)
The Ocean Chemistry of the Early Earth and other Water Worlds

VERONIQUE DEHANT (Royal Observatory of Belgium & UCLouvain)
Lander Radioscience on Mars
Program and Abstracts

9:30-10:00 registration, welcome coffee

EARTH

Invited talk

-10:00-10:40 Francis Albarede
The Ocean Chemistry of the Early Earth and other Water Worlds

Contributed talks

-10:40-11:00 Huan Cui, Ian J. Orland, Kouki Kitajima, Shuhai Xiao, Alan J. Kaufman, Adam Denny, Michael J. Spicuzza, John H. Fournelle, Jean-Marc Baele, Steven Goderis, Philippe Claeys, John W. Valley
A unifying model for the largest carbon isotope negative anomaly in Earth history

-11:00-11:20 Alexandra S. Rodler, Claudio Gaucher, Gerard J. B. Germs, Robert Frei, Steven Goderis, Philippe Claeys
Redox fluctuations in Neoproterozoic post-Snowball Earth environments

-11:20-11:40 Marie Catherine Sforna, Corentin C. Loro, Catherine F. Demoulin, Camille François, Yohan Cornet, Yannick J. Lara & Emmanuelle J. Javaux
Multicellular green algae in Mid-Proterozoic shallow marine environments

-11:40-12:00 Loron C.C., François C., Rainbird R.H, Turner E.C, Borensztajn S. & Javaux E.J.
An early fungus from the Proterozoic of Arctic Canada
-12:00-12:20 T. Déhais\textsuperscript{1,2}, P. Kaskes\textsuperscript{1,2}, S. J. de Graaff\textsuperscript{1,2}, S. M. Chernonozhkin\textsuperscript{3}, V. Debaille\textsuperscript{2}, F. Vanhaecke\textsuperscript{3} Ph. Claeys\textsuperscript{1}, and S. Goderis\textsuperscript{1}

Disentangling cratering processes using non-traditional isotope ratios on core m0077a of the IODP-ICDP expedition 364 in the Chicxulub impact structure.

-12:20 -12:40 Maxwell Thiemens

Extremophile Zinc Isotopes

12:40-13:40 lunch (sandwiches)

BEYOND EARTH

Invited talk

-13:40-14:20 Veronique Dehant, S. Le Maistre, and the LaRa team

Lander Radioscience on Mars

Contributed talks


Modelling the impact of collisions on early Mars

-14:40-15:00 Sébastien Viscardy

A short overview of the mystery of methane on Mars

-15:00-15:20 L. Demaret, G. Eppe, E.J. Javaux, C. Malherbe

Quantitative studies for performance evaluation of Raman spectrometers proposed for Mars exploration missions

15:20-15:50 coffee break

-15:50-16:10 Valentin Fortier, Vinciane Debaille, Véronique Dehant, Benjamin Bultel, Damien Debecker, Yaroslav Filinchuk and Yasuhito Sekine

Methane on Mars: an abiotic origin?
-16:10-16:30 **Jérôme Roland, Vinciane Debaille, Geneviève Hublet**

Caleta el Cobre 02: Implications on the origin of nakhlites

-16:30-16:50 **Bernard Charlier, Mikael Beuthe, Olivier Namur, Attilio Rivoldini, Tim Van Hoolst**

Building the volcanic crust of Mercury

-16:50-17:10 **Michael Gillon**

The TRAPPIST-1 JWST Community Initiative

-17:10-17:30 **Elsa Ducrot, Michaël Gillon, P. Rimmer, M. Turbet on behalf of the Spitzer Red worlds exploration program consortium and the SPECULOOS Team**

SPECULOOS & TRAPPIST-1

**POSTER**

**P.Stefanic¹, B.Begasse de Dhaem¹², D.Lurkin¹, B.Joris¹, M.Delmarcelle¹**

Microfluidic electrophoresis: a technology for the new science and space colonies.

17:30 End of meeting

& Departure to the Christmas market (food, drinks and craft) in Liège historical city center!
Next European Astrobiology meeting: BEACON 2020

Deadline for abstract submission is 15 January 2020.
Deadline for registration is 1st February 2020.
Accommodation booking deadline is 1 February 2020.
The chemistry of planetary oceans is determined by hydrothermal and riverine inputs and by the sedimentary output. The ejection temperature of submarine hydrothermal fluids increases with gravity and water depth, while the tectonic regime and gravity constrain the proportion of the planetary surface subject to weathering. Weathering is the main proton sink, whereas hot hydrothermal fluids are the proton source. The pH of ocean worlds increases when planetary gravity decreases. pH is controlled by seawater alkalinity and primarily Cl$^-$ contents. The abundance of each cation M in hydrothermal fluids is buffered by a series of reactions $[M^{n+}]/[H]^{n+} = K(T)$. The sedimentary output is controlled by mineral solubility (sulfates, sulfides, hydroxides, carbonates, ferric iron), which themselves are controlled by the overall electron balance of the environment. Carbonates, nitrates, and sulfates dominate in oxidized environments at the surface of the modern Earth, but only because of loss of organic carbon by subduction over geological time. Electron availability is higher in abiotic environments, such as the surface of the Earth prior to 2.4 Ga and other planets, which is translated by the dominance of sulfide over sulfate, of ferrous compounds, and by the lack of nitrates and carbonates. The seawater of reducing oceans is dominated by Fe$^{2+}$, Na$^+$, Ca$^{2+}$, and Cl$. Since the only oceanic Mg$^{2+}$ input is runoff, the Fe$^{2+}$/Mg$^{2+}$ ratio of water worlds must be very high. Likewise, riverine PO$_4$ being the only P input, seawater of water worlds cannot be propitious to the emergence of life. Finally, Fe$^{2+}$ dissolved in seawater reacts with atmospheric CO$_2$ to produce CH$_4$ and a variety of mixed Fe$^{2+}$/Fe$^{3+}$ minerals such as magnetite and ferrihydrite. The ocean composition therefore varies with planetary radius, the depth of the ocean, the tectonic regime, and to a lesser extent the composition of the mantle.
Unique physical and chemical characteristics of Mercury have been recently revealed by measurements from NASA’s MESSENGER spacecraft. The closest planet to our Sun is made up of a large metallic core that is partially liquid, a thin mantle thought to be formed by solidification of a silicate magma ocean, and a relatively thick crust. The crust of Mercury was built over the first billion years of the planet by intense volcanic activity. Mantle melting and emplacement of lava to the surface produced a secondary magmatic crust varying spatially and over time in composition and mineralogy. We have made calculations of the thickness of the crust using the MESSENGER gravity and topography data and taking into account lateral variations of crustal density. The mineralogy at the surface translates to pore-free crustal densities of 2,800-3,150 kg.m$^{-3}$. Maximum crustal density (3,100-3,150 kg.m$^{-3}$) is found in High-Mg regions that are forsterite-dominated and plagioclase-poor. The lightest crust (2,750-2,800 kg.m$^{-3}$) is found in Al-rich regions such as the North Volcanic Plain that are plagioclase-dominated. We find that the calculated local thickness of the crust is correlated with the degree of mantle melting calculated using surface compositions obtained by X-ray spectrometry on board MESSENGER. Low-degree melting of the mantle below the Northern Volcanic Plains produced a thin crust while the highest melting degree in the ancient High-Mg region produced the thickest crust, excluding mantle excavation by an impact in that region. The correlation between crustal thickness and mantle melt production also exists for the oceanic crust on Earth and might be a common feature of secondary crusts on terrestrial planets.
A unifying model for the largest carbon isotope negative anomaly in Earth history

Huan Cui\(^1,2\)*, Ian J. Orland\(^3\), Kouki Kitajima\(^3,4\), Shuhai Xiao\(^5\), Alan J. Kaufman\(^6\), Adam Denny\(^3\), Michael J. Spicuzza\(^3\), John H. Fournelle\(^3\), Jean-Marc Baele\(^7\), Steven Goderis\(^1,2\), Philippe Claeys\(^1,2\), John W. Valley\(^3,4\)

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The globally-recorded Ediacaran Shuram Excursion (SE) represents the largest carbonate carbon isotope (\(\delta^{13}C_{\text{carb}}\)) negative anomaly in Earth’s history. Typically, the SE is characterized by \(\delta^{13}C_{\text{carb}}\) values that plunge to a nadir of ca. \(-10\)‰ over a short stratigraphic interval and then rise steadily in the overlying tens or hundreds of meters before recovering to baseline values of ca. \(+5\)‰. It was recently hypothesized that \(^{13}\)C-depleted authigenic carbonates may have contributed to the SE. Supporting evidence for this hypothesis has been found in South China, where an atypical SE at the outer shelf Zhongling section has been arguably correlated with the typical SE at the inner shelf Jiulongwan section. Despite intensive studies, no samples from the SEs in South China have been investigated at micrometer scales. To better understand the genesis of the SE and the role of authigenic calcites played in this event, we conducted a detailed study of the SEs at two sections of different water depth via \(\mu\)XRF, CL, SEM, and SIMS (\(\text{in situ}\), 7 mm spots). SIMS results of calcites and dolomites from the two studied sections in South China reveal distinct \(\delta^{13}C_{\text{carb}}\) values. The SIMS \(\delta^{13}C_{\text{carb}}\) data of the inner shelf Jiulongwan section show relatively narrow and homogeneous ranges of \(\delta^{13}C_{\text{carb}}\) values. In striking contrast, the SIMS \(\delta^{13}C_{\text{carb}}\) data of the outer shelf Zhongling section show a significantly wide range of over 40‰, with negative values (from \(-37.5\)‰ to \(-9.3\)‰, mean \(-23.2\)‰) in authigenic calcites and positive values (mean \(+2.0\)‰) in shallow marine dolomites. We propose that the contrasting expressions of \(\delta^{13}C_{\text{carb}}\) signals in different minerals and sections were caused by difference locales of geochemical reactions. The SIMS data in this study represent a depositional spectrum from primary shallow seawater signals (recorded in the Zhongling dolomites), to altered bottom seawater signals (recorded in the Jiulongwan calcites), to early diagenetic signals (recorded in the Zhongling dolomites), and to potentially late diagenetic signals (recorded in the Jiulongwan dolomites). If our interpretation based on samples from South China is correct, the globally recorded SEs may represent a profound bottom-seawater anomaly in restricted continental margins that are decoupled from the Ediacaran open ocean.
IODP-ICDP EXPEDITION 364 IN THE CHICXULUB IMPACT STRUCTURE

T. Déhais¹,², P. Kaskes¹,², S. J. de Graaff¹,², S. M. Chernonozhkin³, V. Debaille², F. Vanhaecke³ Ph. Claeys¹, and S. Goderis¹

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Introduction: The Chicxulub impact structure, located on the Yucatán peninsula of Mexico, has been drilled by the IODP-ICDP Expedition 364 in 2016. A continuous sequence of the upper peak-ring has been retrieved from Site M0077A. This core is from top to bottom composed of ~110 m of Paleogene sediments, ~130 m of suevite and impact melt rocks, and ~590 m of crystalline and metamorphic basement lithologies [1]. The suevite complex deposition is the result of several processes, including the fall-back of material ejected by the impact, slump and avalanches on the peak-ring, and wash-back by tsunami waves within the crater [2]. Therefore, the suevite was likely exposed to different thermodynamic processes during its deposition, as was the case for the impact melt rocks. In addition, the whole core has been the subject of severe hydrothermal alteration, potentially overprinting any primary compositional and isotopic signatures [3].

The Fe, Zn, and Cu isotopic composition of 27 samples from various units within core M0077A is combined with major and trace element data and petrographic observations. The main objectives are to disentangle the different processes affecting the various units of the upper peak-ring, such as mixing of distinct target lithologies, tracing potential volatilization or condensation effects (as observed for sulfur [4]), and determining the degree of post-impact hydrothermal alteration.

The choice of the Fe, Zn, and Cu stable isotope systems here is motivated by the relative abundance of these elements in the samples, their distribution among different mineral phases, and their difference in volatility with a 50% condensation temperature of 1334K for Fe (medium refractory), 1037K for Cu (semi-volatile), and 726K for Zn (highly volatile) [5 ; 6]. Because of these different condensation temperatures, the isotopic ratios of these elements may exhibit variations inherited from distinct thermodynamic environments and time intervals during crater formation.

Sample Selection and Methods: All data were obtained by bulk analysis on homogenized powdered samples. The isotopic compositions of Fe, Zn, and Cu were determined using MC-ICP-MS, following established ion-exchange chromatographic procedures. Major and trace element compositions were obtained using ICP-OES and ICP-MS, with total sample dissolution based on alkaline fusion of homogenized sample powders. Particular attention was paid to the transitional interval, including five samples between 616.58 to 617.33 meters below sea floor (mbsf), suevite unit, with twelve samples between 617.34 to 721.62 mbsf, and upper impact melt interval,
characterizing three samples between 721.62 to 747.02 mbsf, as these parts of the core may have been affected more strongly by distinct thermodynamic conditions. The three samples from the upper impact melt sheet range from macroscopically homogeneous black clast-poor melt rock to dark green impact melt rock (with schlieren), containing angular black melt fragments [1]. In addition, several samples have been selected from the granitoid basement material, including two granites, two dolerite dikes, one metamorphic clast, and two lower impact melt rocks from between 747.02 to 1334.69 mbsf [7].

**Results and Discussion:** For both Fe and Zn, the isotopic compositions of most samples are in range of UCC values. This is the case for all main units within the core M0077A, including the transitional unit, the upper peak-ring sequence (suevite and upper impact melt rocks), and the lower peak-ring sequence (granitoid basement and dikes, and lower impact melt rocks). The Fe and Zn isotope ratios mainly detect the admixture of distinct target lithologies within particular units. However, there are still some isotopic heterogeneities preserved within the core, likely driven by distinct lithological or mineralogical carriers.

Possible hints of volatilization or condensation in the M0077A core of the Chicxulub impact event appear to be overprinted by post-impact hydrothermal alteration, except in the suevite, where the Cu isotope ratio tends to show preservation of the volatilization process.

Further isotopic analyses on 10 additional samples selected throughout core M0077A will allow a complete overview and will further develop these initial results.

The LaRa (Lander Radioscience) experiment is designed to obtain coherent two-way Doppler measurements from the radio link between the 2020 ExoMars lander (the Kazachok surface platform) and Earth during at least one Martian year. The Doppler shifts are measured by comparing the frequency of the radio signal received from LaRa with the known frequency of a ground-based reference signal. Transmitting signals from Earth to Mars and back again is called two-way communication and greatly enhances the accuracy of the radio experiment. The Doppler measurements are used to determine the orientation and rotation of Mars in space (precession, nutations, and length-of-day variations), as well as polar motion, more accurately than ever before. The LaRa transponder is designed to maintain the phase coherence of the signal, and the global precision on the Doppler measurements is expected to be better than 0.1 mm/s for a 60-second integration time (compared to instrument precision requirements at the level of 0.02 mm/s for a 60-second integration time). The final objective is to obtain new information and constraints on the interior of Mars, and on the sublimation and condensation cycle of atmospheric CO$_2$. Rotational variations will allow us to constrain the moments of inertia of the whole planet, including its mantle and core, moments of inertia of the core only, and seasonal mass transfer between the atmosphere and ice caps. In the meantime, we have data from the InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) RISE experiment (Rotation and Interior Structure Experiment), which we will discuss as well. The LaRa experiment will be combined with other ExoMars experiments in order to retrieve a maximum amount of information. We will also combine LaRa’s Doppler measurements with similar data from the Viking landers, Mars Pathfinder, Mars Exploration Rovers, and the ongoing InSight/RISE mission, will provide information on the interior of Mars with unprecedented accuracy, improving our understanding of the formation and evolution of the Red Planet.
Quantitative studies for performance evaluation of Raman spectrometers proposed for Mars exploration missions

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Two new exploration missions (ESA ExoMars 2020 & NASA Mars 2020) will be launched to Mars next year to address key scientific objectives such as the past habitability of the planet and its potential to host life. Both missions will comprise a Rover to investigate ancient sites using analytical payload instrumentations capable of mineral characterisation and also detection of potential signatures of life (biomarkers) preserved in rocks [1,2]. These instrumentations will include for the first time Raman spectrometers which enable molecular identification and quantification of organic and inorganic materials. In the context of planetary exploration, Raman spectroscopy has demonstrated valuable capabilities such as the ability to detect specific molecular markers from samples in extreme terrestrial environments (Mars analogue sites) including extremophiles signatures [3-6]. Clearly, the successful Raman interrogation of a microbial colonization or any structured deposits in a sample is facilitated by a comprehensive sample handling and appropriate sample preparation, visualisation of desired sample spatial arrangements, and questioning the micrometric location of interest with the appropriate laser excitation source. However, Raman analyses on Mars will be operated \textit{in-situ} with a single excitation source and limited acquisition parameters on powdered rocks (i.e. loss of spatial context during sample drilling and crushing), from which the detection of a dispersed biomarker in a multi-compositional mix will be more challenging. In accordance with this scenario, automated Raman procedures on solid dispersions have to be developed for the detection of trace analyte quantities under mission-representative measurement conditions. Such methodologies are necessary for determining the performances (e.g. the limits of detection reliably achievable for target organic compounds) of flight spectrometers in use for forthcoming missions on Mars or for the development of other spectrometers such as anticipated for the exploration of Europa. Consequently, we developed analytical methods based on model dispersions of gypsum spiked with known quantities of L-cysteine. First, large spectral datasets were obtained from Raman mapping (benchtop micro-spectrometer) to obtain intensity estimates representative of the admixtures content. A Raman subsampling strategy relying on confidence intervals was then established to determine the precision of intensities resulting from reduced dataset sizes akin to set sizes of mission measurement procedures [7]. Quantitation of this amino acid in gypsum from restricted point-by-point interrogation was demonstrated (at stated confidence levels) and also could be extended to other analytes such as β-carotene. The methodology was further implemented to more complex mixtures made up of gypsum and calcite (prepared in different proportions) spiked with L-cysteine. This optimised quantitative model developed from ternary mixtures enabled to simultaneously quantify the amount of amino acid and to determine the composition (relative proportion) of calcite and gypsum in any test mixture. Eventually, the method was transferred to a miniaturised Raman spectrometer with specifications (laser wavelength, laser spot size, irradiance range, spectral resolution[8]) similar to the ExoMars 2020 Raman Laser Spectrometer (RLS) and confirmed these results.
SPECULOOS & TRAPPIST-1

Elsa Ducrot (1), Michaël Gillon (1), P. Rimmer (2), M. Turbet (3) on behalf of the Spitzer Red
worlds exploration program consortium and the SPECULOOS Team

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The nearest ultracool dwarf stars (UCDs), i.e. very low mass stars with spectral type later than
M6, represent a promising opportunity to make the young field of exoplanetology enter the
realm of temperate Earth-sized worlds. The SPECULOOS transit survey (Search for habitable
Planets EClipsing Ultra COOL Stars) ventures into the largely uncharted territory of UCDs to
seek for transits of temperate terrestrial planets, probe their diversity, and ultimately assess
their potential habitability. The discovery of the nearby (~12 parsecs) TRAPPIST-1 (aka
SPECULOOS-1) system by the SPECULOOS prototype ongoing on the TRAPPIST-South
telescope has proved this approach to be very promising. This system is composed of an M8-
type dwarf star orbited by seven nearly Earth-sized, temperate planets, three of them being
in its habitable zone. Considering their transiting nature, the infrared brightness (K=10.3) and
the Jupiter-like size of their host star, these planets are extremely promising candidates for
the first thorough atmospheric characterizations of temperate terrestrial worlds with
upcoming facilities such as the James Webb Space Telescope (JWST). Nonetheless, before we
can hope for any atmosphere detection all sources of limitation must be identify and quantify.
Notably through a multi-epoch multi-wavelengths photometric follow up of the planets’
transits. In this context, we carried out an intensive space (K2 and Spitzer space telescopes)
and ground based (TRAPPIST, Liverpool, UKIRT, VLT and SPECULOOS telescopes) photometric
monitoring program, with a total of 365 transits observed from the optical to the infrared.
In the first part of my talk, I will shortly introduce the SPECULOOS photometric survey and in
the second part of my talk I will focus on the TRAPPIST-1 system and show how we tried to
make the most of our unique dataset with the aim to (1) explore the system for new transiting
planets, (2) to refine the parameters of the known planets, (3) to constrain the planet’s orbital
dynamics and bulk compositions with the transit timing variation method, and (4) to construct
a wider broadband spectra for each planet to quantify the impact of stellar effects on
atmospheric characterization and habitability (namely transit light source effect and flares).
Methane on Mars: an abiotic origin?

Valentin Fortier, Vinciane Debaille, Véronique Dehant, Benjamin Bultel, Damien Debecker, Yaroslav Filinchuk and Yasuhito Sekine

ROB/UCL, ULB

Methane on Mars is a hot topic for many reasons. Source(s) and removal process(es) remain currently unknown; its detection is still uncertain; and we don't know if this methane is related to a biological activity. In this work, we focus on the possible sources for this methane and more especially on abiotic ones, with processes such as serpentinization; Fisher-Tropsch Type reactions, and Sabatier process. The aim here is to experimentally determine the production capacity of H2 and then CH4 with those abiotic processes in past and current martian conditions to determine the viability of this source. The futur results of this work will be linked with a biological approach to determine if there is a possible link with some living beings, since H2 and CH4 can be nutriments or products of a biological activity.
The TRAPPIST-1 JWST Community Initiative

Michaël Gillon
ExoTIC Lab - UR Astrobiology, ULiege

During the last decade, dozens of transiting giant exoplanets have had their atmospheric properties characterized in some detail by various space-based and ground-based telescopes. The upcoming launch of JWST combined with the recent discovery of the TRAPPIST-1 planetary system represents a unique opportunity to extend such atmospheric studies into the realm of temperate Earth-sized worlds. Indeed, the proximity of the system (12pc) combined with the Jupiter-like size and small luminosity (0.05% of the Sun's) of the star make the comparative study of the planets’ atmospheres within reach of an ambitious (100hr to 1000hr) JWST program. Given the limited lifetime of JWST and the numerous challenges that this study will face both from an observational and a theoretical point of view, the TRAPPIST-1 JWST Community Initiative aims to ensure its coordination and optimization. It will be managed by a board of scientists with complementary expertise who will help provide coordination mechanisms for all members of the community ready to join and support the initiative.

While keeping the freedom to publish scientific results independently, the involved scientists will act as a community to develop a well-defined sequential structure for the study of the system with JWST and to coordinate on every aspect of its preparation and implementation, both on the observational (e.g. study of the instrumental limitations, data analysis techniques, complementary space-based and ground-based observations) and theoretical levels (e.g. model developments and comparison, retrieval techniques, inferences). All JWST data taken within this community-driven approach will have a minimal proprietary period, so to maximize their scientific return. Depending on the outcome of the first phase of observations, this initiative could become the seed of a major JWST legacy program partially or totally devoted to the study of TRAPPIST-1.
Modelling the impact of collisions on early Mars


G-Time ULB, and collaborators

The origin of the formation of the martian valley networks is now a nearly 50 year old mystery. It has been proposed that large bolide impacts could have triggered a long-term climate change conducive to the formation of these valley networks (Segura et al., 2002, 2008, 2012). Here we use a hierarchy of numerical models (a 3-D Global Climate Model, a 1-D radiative-convective model and a 2-D Mantle Dynamics model) to test that hypothesis and more generally explore the environmental effects of very large bolide impacts ($D_{\text{impactor}} > 100$ km) on the atmosphere, surface and interior of early Mars.

We show that the environmental effects of the largest impact events recorded on Mars are characterized by: (i) a short impact-induced warm period (several tens of Earth); (ii) a low amount of hydrological cycling of water; (iii) deluge-style precipitation ($\sim 2.6$ m Global Equivalent Layer of surface precipitation per Earth year; (iv) precipitation patterns that are uncorrelated with the observed regions of valley networks, and (v) significant disturbance of the upper mantle convection pattern. Moreover, we show that the impact-induced stable runaway greenhouse state predicted by Segura et al. (2012) is physically inconsistent. Using 2-D Mantle Dynamics simulations we find that large bolide impacts can produce a strong thermal anomaly in the mantle of Mars that can survive and propagate for tens of millions of years. This thermal anomaly could raise the near-surface internal heat flux up to several hundreds of mW/m$^2$ (i.e. up to $\sim 10$ times the ambient flux) for several millions years at the edges of the impact crater. However, such internal heat flux is largely insufficient to keep the martian surface above the melting point of water.

Altogether with the poor temporal correlation between the formation of the largest basins and valley networks, these arguments indicate that the largest impact events are unlikely to be the direct cause of formation of the Noachian valley networks. Our numerical results support instead the prediction of Palumbo and Head (2018) that very large impact-induced rainfall could have potentially erased the previously visible morphological surface history and be consistent with the timing of formation of clays.
An early fungus from the Proterozoic of Arctic Canada

Corentin C. Loron*1, Camille François1, Robert H. Rainbird2, Elizabeth C. Turner3, Stephan Borensztajn4, Emmanuelle J. Javaux1

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Fungi play a key role in extant ecosystems. They are thought to have had an important role in the colonization of land by eukaryotes, and in the thriving of land plants and metazoans on the continents. However, macro- or microfossils that can unambiguously be identified as fungi are absent from the fossil record until the middle of the Palaeozoic era (Ordovician). Interpreting the biological affinities of ancient minute microfossils is difficult, sometimes even at the level of Domain and morphological comparisons must be coupled with ultrastructural approaches and new analytical tool in spectroscopy to interpret their affiliation at a lower taxonomic level (Kingdom or even sub-Kingdom). Following this principle, we present Ourasphaira giraldae, an organic-walled microfossil extracted from shales of the ~900 Ma Grassy Bay Formation, Arctic Canada, interpreted as an early representative of Fungi. These microfossils are more than half a billion years older than previously reported Paleozoic representatives of fungi, an age consistent with data from molecular clocks for the emergence of this clade. This discovery extends the fossil record of the fungi but also pushes back the minimum age for the appearance of the eukaryotic crown group Opisthokonta, which comprises metazoans, fungi and their protist relatives.
Redox fluctuations in Neoproterozoic post-Snowball Earth environments

Alexandra S. RODLER 1,2 *, Claudio GAUCHER 3, Gerard J. B. GERMS 4, Robert FREI 1, Steven GODERIS 2, Philippe CLAEYS 2

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The Neoproterozoic Era witnessed dramatic environmental changes with global low latitude glaciations in the Cryogenian Period, followed by a significant rise in environmental oxygenation. These events may have set the stage for the evolution of first macroscopic organisms in the Ediacaran Period. However, the biogeochemical changes that occurred in post-glacial marine environments need to be constrained in more detail before we can evaluate the implications for the evolution of early life.

To elucidate the environmental conditions following the Sturtian glaciation (ca. 717 Ma), we use carbonate sediments of the Otavi and Witvlei Groups, Namibia, that were deposited after the syn-Sturtian Chuos glaciation. We evaluate these paleo-environmental conditions in a chemo-stratigraphic approach with an emphasis on the novel chromium stable isotope system (denoted as δ53Cr). Due to its redox-sensitivity and potential for being faithfully recorded by carbonates, this isotope system is a promising tool for tracing fine-scale redox fluctuations in past marine environments. We apply this tracer system paired with traditional isotope systems, trace and rare earth elements.

The Chuos δ53Cr signal is largely within the range of bulk silicate Earth (BSE), where a hydrothermal influence is also indicated by positive Eu anomalies (>1.1). This is followed by fluctuating, but generally high δ53Cr values (~+0.1‰) relative to BSE and negative Ce anomalies (<0.9) as well as typical Neoproterozoic marine δ13C and δ18O values (~+4‰ and ~-3‰, respectively). In summary, our results indicate fluctuating, but overall sufficiently high oxygen levels to oxidize and mobilize Cr during weathering processes on land as well as to stabilize these positively fractionated Cr-isotope values in marine environments. Such small-scale fluctuations in oxygen levels might have promoted the diversification of early life.
Multicellular green algae in Mid-Proterozoic shallow marine environments

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Photosynthetic eukaryotes are key constituents of the modern ecosystems. Their appearance is an essential step in the evolution of life and of the Earth, making possible the colonization of land. This evolution and especially the one of green algae is not well constrained as no unambiguous green algae fossil was identified before the Neoproterozoic. The identification of these fossils lays on their comparison to modern algae but the distinct characteristics that make modern organism green algae, i.e. presence of chloroplast bound by a two-membrane envelope and containing chlorophyll a and b, as well as the production and storage of starch as photosynthethic reserve, are scarcely preserved. Important work has been done to characterize the ultrastructure and the chemical composition of the microfossils to obtain new tracers of the belonging to a class or family of eukaryotes. However, none of these approaches permit to detect the presence of chlorophyll, an essential criteria of recognition of phototrophy.

We report here the results of a morphological (optical microscopy, SEM), ultrastructural (TEM), spectroscopic (Raman and FTIR), and geochemical analyses (Synchrotron-based XRF and XANES) lead on the fossil Arctacellularia tetragonala. A. tetragonala is a readily identifiable microfossil, with barrel-shaped cells in chain and lanceolate folds. It is ubiquitously found in coeval sedimentary deposits from the Mid-Mesoproterozoic to the Neoproterozoic. The investigated fossils come from the Congo basin (Mbuji-Mayi Supergroup, DRCongo, ~1000Ma), which was deposited in shallow marine environment. Numerous Intracellular Inclusions (ICI), thought to be condensed cytoplasm, can be found in these fossils, making them a unique opportunity to study their metabolism.

A reinvestigation of this microfossil evidenced true dichotomous branching patterns with specialized nodal cell, suggesting that A. tetragonala can be classified as a eukaryote (before it was considered as a probable eukaryote). The study of the metal distribution within these fossils, highlighted specific pattern of distribution of metals in the considered taxon. Metals are mainly concentrated in the organic walls of the fossils (Fe>> Ni, Cu, Zn), with higher concentration in the fossil folds. In addition, Ni is specifically enriched in the ICIs. Raman analysis on ICI did not reveal the presence of mineral phases, suggesting that the Ni is bound to organometallic compounds in the fossils. XANES investigation of the redox state of Ni in the ICI revealed that Ni is contained in porphyrins, which are diagenetic chlorophyll derivatives.

This combined approach allow us to put in evidence the earliest direct evidence of eukaryotic photosynthesis and to conclude that A. tetragonala was a eukaryotic phototroph, part of the Archaeaplastida and putatively belonging to the green lineage. For the first time we were able to classify Precambrian microfossils not in term of morphology but in term of metabolism.
Microfluidic electrophoresis: a technology for the new science and space colonies.

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Free Flow Electrophoresis (FFE) is a separation technology experimented successfully during STS space missions. Indeed, in microgravity environment, it demonstrated outstanding performances in purifying valuable cells and chemicals, otherwise difficult to recover on Earth in that time.

FFE can be operated in different modes such as FFITP (Free Flow Isotachophoresis) or FFIEF (Free Flow Isoelectrofocusing). The most widely used mode is FFZE (Free Flow Zone Electrophoresis) which is very similar to CZE (Capillary Zone Electrophoresis). A hydrostatic pressure pushes a flow of background electrolytes into a separation chamber (SCH) made from two glass plates with insulated spacers on the sides. Samples are injected into the SCH where electrodes are embedded. An electric field is applied orthogonally to the flow thus separating entities from the sample according to their actual electrophoretic mobilities.

FFE proved to be effective at separating various charged entities from small ions to whole cells. Its main advantages are it is free of any stationary phase and it is considered as gentle for some sensitive materials. Since interactions are preserved with FFE, hot topics in modern biology as life emerging from molecular network and the rule of non-coding RNA could be studied with such a tool. Furthermore, FFE is one of the few real continuous separation technologies thus reducing its footprint and the need to store raw material contrary to most of the currently used separation technologies. As such it could be of interest for any ambitious scientific project where room space is limited.

Nonetheless, FFE suffers also from some drawbacks. There are indeed some dispersive effects as, e.g, Joule effects and electrohydrodynamic dispersion that hinder the effectiveness of the separation in terms of resolution and steadiness. Many drawbacks are due to the millimetric scale of the SCH. Furthermore, embedded electrodes generate electrolysis bubbles which impair heavily the fluidic stability to the point the separation cannot last steadily for long or even is stopped.

Consequently, reducing the scale of the SCH to micrometers can overcome most of the dispersive effects and enables the chamber to work as in microgravity. Also operating so called liquid electrodes get rid of bubbles which allow in turn to run long-lasting steady continuous separations.

We demonstrate a new manner to build a microfluidic chip dedicated to µFFE (microfluidic-FFE). The SCH is 50µm high and made from two glass plates enclosing a polyimide microfluidic circuit. With such device we demonstrate we did separate successfully proteins as well as small chemicals for several days in a steady manner. We also demonstrate the so built µFFE device is as effective or even overcome some widely used chromatographic resins.

As a consequence, in future space explorations by human, µFFE could become a robust and 3D printable technology without the need of consumables (resin or membrane) which is advantageous to sustain food, drug and raw material production.
Nakhlites are martian clinopyroxene-rich and olivine cumulates. These meteorites are considered to be originated from a unique magmatic system in a single pile of cumulates. CeC022 is a new nakhlite found in the Atacama desert in 2016. This meteorite was dated using 147Sm-143Nd and 176Lu-176Hf methods. It shows similar crystallization age and ejection age (3He, 21Ne and 38Ar) as the other nakhlites. On the other hand, the physical as well as the chemical properties of the newly discovered nakhlite imply that CeC022 probably originates from a previously unsampled flow of the same magmatic system, therefore increasing nakhlites diversity.
A short overview of the mystery of methane on Mars

Sébastien Viscardy  
Royal Belgian Institute for Space Aeronomy (BIRA-IASB)

Several detections of methane in Mars’ atmosphere have been reported over the last 15 years. As this gas is a potential biomarker, its presence could provide evidence of extinct or extant life on the planet. However, those results have triggered intense debates and raised skepticism mainly for two reasons: first, because the detections are not fully convincing and second because the observed behavior of methane cannot be explained by known atmospheric chemistry and physics. We will provide an overview of those problems, especially in the light of the measurements collected by NOMAD and ACS onboard the ExoMars Trace Gas Orbiter.
Extremophile Zinc Isotopes

Maxwell Thiemens
G-TIME, ULB

The earliest lifeforms leave little evidence of their passing, making the reconstruction of life's origins difficult. Fortunately, chemical fossils provide an alternative mechanism for tracing biological activity. The categorization of different elements requires understanding modern biological processes before it can be used accurately in interpreting the geological record. In our study, we examined three species of methanogenic archaea using zinc isotopes. I will discuss the effects of varying levels of temperature on the isotopic record, and the implications this has for Zn as a bio-proxy.
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