Abstracts & Program of the Joined meeting

FNRS Contact Group "Astrobiology: from stars and planets to extreme life" – Annual meeting 2014 & IUAP Planet TOPERS meeting – second annual meeting

Monday 3d November 2014
University of Liège
Geology Department Room 125, B18
Allée du 6 Août, 17 Liège (Sart-Tilman) 4000

Invited speakers:

LUCAS STAL (Darwin Center project leader, Royal Netherlands Institute for Sea Research NIOZ): "Microbial mats: a living entity"

DENNIS HÖNNIG (DLR Berlin, Germany)
"A Thermal Evolution Model of the Earth Including the Biosphere, Continental Growth and Mantle Hydration"

Organization: V. Dehant & E. Javaux, with the help of J. Schmetz & M. Guadagnano

Program

starting time	Speakers	Titles
9h30	***welcome coffee***	
9h50	**Lucas Stal (Invited talk) (NIOZ, The Netherlands)**	**Microbial mats: a living entity**
10h30	Jérémie Beghin (ULg), Simon Poulton, Nur Gueneli, Jochen Brocks, Jean-Yves Storme, Christian Blanpied, Jean-Pierre Houzay, Emmanuelle Javaux	Biodiversity and redox conditions through the Proterozoic Taoudeni basin of Mauritania.
10h45	Luc Cornet (ULg), Emmanuelle Javaux, Annick Wilmotte, Herve Philippe, Denis Baurain	A Phylogenomic analysis of the origin of plastids.
11h00	Blaise K. Baludikay (ULg), Andrey Bekker, Daniel Baudet, Jean-Yves Storme, Emmanuelle J. Javaux	Biostratigraphic and chemostratigraphic constraints of the Mbuji-Mayi Supergroup (Meso-Neoproterozoic age), Democratic Republic of Congo.
11h15	Jean-Yves Storme (ULg), Emmanuelle J. Javaux	Carbonaceous material characterization of the 3.2 Ga Mapepe Fm, Fig Tree Group, Barberton Greenstone Belt, South Africa (BARB 5 drill core, ICDP Project, Cradle of Life): new insights from Micro Raman Spectroscopy analysis
11h30	Camille François (ULg), Pascal Philippot, Patrice Rey, Daniela Rubatto	Burial and exhumation during Archean sagduction in the East Pilbara Granite-Greenstone Terrane, Australia
11h45	Nadine Mattielli (ULg), P. Haenecour , G. Hublet, and V. Debaille	Correlated Mg-Zn isotope fractionation in Archean komatiitic lava-flows.
12h00	Matthew S. Huber (VUB), S. Goderis, V. Debaille, and P. Claeys	Very high Ni olivine in a porphyritic cosmic spherule
12h15	Geneviève Hublet (ULB), V. Debaille, Q-Z. Yin	Chronology of differentiation and magmatic activity in 4-vesta using 26Al-26Mg model age.
12h30	Nadia Van Roosbroek (ULB), L. Pittarello, V. Debaille, Ph.Claeys	Formation of the IIE non-magmatic iron meteorites
12h45	***lunch***	
13h30	Y. Hidaka, N. Shirai, A. Yamaguchi, 4, M. Ebihara, and V. Debaille	Chemical composition of primitive achondrites: Clues for understanding the early differentiation processes of their parent bodies.
13h45	Seann McKibbin (VUB), Lutz Hecht, Hermann Terryn, Philippe Claeys	Metamorphism in the EH chondrite parent body recorded by minor elements in accessory olivine.
14h00	Fatima EL Atrassi (ULB), V. Debaille, N. Mattielli, J. Berger	Geochemistry of Archean Mafic Amphibolites from the Amsaga Area, West African Craton, Mauritania: What is the Message?

14h15	**Dennis Hönnig (Invited talk) (DLR Berlin, Germany)**	**A Thermal Evolution Model of the Earth Including the Biosphere, Continental Growth and Mantle Hydration.**
14h55	Vinciane Debaille (ULB) and Craig O'Neill	When did plate tectonics begin?
15h10	Oscar Laurent, Hervé Martin, Jean-François Moyen, Armin Zeh, Régis Doucelance	The secular evolution of archean granitoids: evidence for the onset of "modern-style" plate tectonics between 3.0 and 2.5 ga ago
15h25	Bernard Charlier (ULg), Olivier Namur, Max Collinet	Surface lavas, mantle sources, and sulfur on Mercury
15h40	Cédric Gillmann (ROB)	Atmosphere/mantle coupling on Venus and long term planetary evolution.
16h00	*coffee*	
16h15	Severine Robert (BISA), S. Chamberlain, F. Daerden, A. Mahieux, L. Neary, I. Thomas, S. Viscardy, V. Wilquet, A.C. Vandaele	Potential synergies in the infrared to retrieve methane on Mars using ExoMars Trace Gas Orbiter instruments.
16h30	***coffee***	
16h45	Elodie Gloesener (ROB), Vu T., Choukroun M., Ibourichene A., Hodyss R., Karatekin Ö., and Dehant V.	Experimental measurements of the effect of ammonia on the stability of clathrate hydrates, with tetrahydrofuran as a proxy for methane, and implications for outgassing on Titan.
17h00	Lena Noack (ROB), D. Höning, H. Lammer, and J.H. Bredehöft	Geophysical constraints for the possible habitability of ocean worlds
17h15	Emeline Bolmont (Unam), Raymond, S. N., Selsis, F.	Dynamics of exoplanetary systems, links to their habitability
17h30	Monika Lendl (ULg), Michaël Gillon, Emmanuël Jehin, Valérie Van Grootel	News from Belgian Planet Searches: SPECULOOS & TRAPPIST
17h45	Ludmila Carone (KULeuven)	From vortices to stream dominated: Phase change in the atmosphere dynamics of tidally locked terrestrial planets with Earth-like insolation
18h00	Christian Muller (BISA) and the ASTROMAP consortium	The ASTROMAP EU FP-7 programme : a preparatory step to astrobiology in Horizon 2020.
18h15	Plesa Ana-Catalina (DLR), Tosi Nicola, Grott Matthias, Breuer Doris	How large are present-day heat flow variations across Mars' surface?
18h30	***End of the meeting***	

4th November 2014

10 am-4pm-IUAP Planet TOPERS Executive meeting — Brussels (open only to EC members)
5pm-7pm-Collège Belgique lecture (in French) "Habitability in the solar system" by A Morbidelli (Nice Observatory) and V Dehant (ORB)–Palais des Académies, Brussels (Open to all)

ABSTRACTS (BY ORDER OF PRESENTATION)

BIODIVERSITY AND REDOX CONDITIONS THROUGH THE PROTEROZOIC TAOUDENI BASIN OF MAURITANIA

Jérémie Beghin[1], Simon Poulton[2], Nur Gueneli[3], Jochen Brocks[3], Jean-Yves Storme[1], Christian Blanpied[4], Jean-Pierre Houzay[5], Emmanuelle Javaux[1]

1. University of Liège, Liège, 4000, Belgium; 2 University of Leeds, Leeds, LS2 9JT, United Kingdom; 2.Australian National University, Canberra, ACT 0200, Australia; 3.TOTAL, Projets Nouveaux, Paris, France; 4 TOTAL, Fluids and Geochemistry Dept., Pau, France (retired).

Prokaryotes and microscopic eukaryotes are known to have appeared well before the Cambrian's adaptative radiation, when the macroscopic world flourished. What do we know about the trigger events which stimulated eukaryotic diversification during the Proterozoic? Biological innovations or environmental changes, and indeed probably both, played a fundamental role controlling this important step of life's evolution on Earth. A diversification pattern of early eukaryotes divided into three steps and focusing on different taxonomic levels of the domain Eukarya, from stem group to within crown group, remains to be tested. Supercontinent formation and break-up, widespread glaciations, meteor impacts, atmosphere and ocean oxygenation and chemistry are the main environmental changes which have probably led to eukaryotic diversification. A stratified ocean, during the so-called 'boring billion' (~ 1.8-0.8 Ga), with anoxic ferruginous deep water, euxinic mid-depths, and oxygenated shallow-waters, is thought to have delayed eukaryotic diversification after the Great Oxidation Event (~ 2.4 Ga) by restricting eukaryote evolution and limiting nutrient availability.

Here we present new, exquisitely preserved and morphologically diverse assemblages of organic-walled microfossils from three drill cores of the ~ 1.1 Ga Atar/El Mreïti Groups (Taoudeni Basin, Mauritania, Northwestern Africa). These assemblages include beautifully preserved microbial mats comprising pyritized filaments, prokaryotic filamentous sheaths and filaments, microfossils of uncertain biological affinity including smooth isolated and colonial sphaeromorphs (eukaryotes and/or prokaryotes), diverse protists (ornamented and process-bearing acritarchs), as well as purported green algae and multicellular microfossils interpreted in the literature as possible xanthophyte algae. Several taxa are reported for the first time in Africa, but are known worldwide. Palynofacies and Raman microspectroscopy analyzes were performed to investigate thermal maturity and the preservation state of organic matter; iron speciation was also conducted to reconstruct the ocean palaeoredox conditions.

This study improves the microfossil diversity previously reported and demonstrates the presence of unambiguous eukaryotes. These new microfossil assemblages, in combination with global data sets, provide evidence of early and worldwide diversification of eukaryotes around 1 billion years ago. To better understand the palaeobiology (stem or crown group, aerobic or anaerobic metabolism) and palaeoecology (habitat diversity) of these early eukaryotes, we are combining morphological, microchemical, ultrastructural and quantitative analyzes of microfossils with a high-resolution characterization of eukaryotic biomarkers and palaeoenvironmental and palaeoredox proxies.

A PHYLOGENOMIC ANALYSIS OF THE ORIGIN OF PLASTIDS

Luc Cornet [12], Emmanuelle Javaux [2], Annick Wilmotte [3], Herve Philippe [4], Denis Baurain [1]

[1] Eukaryotic Phylogenomics, University of Liège, Belgium; [2] Palaeobiogeology-Palaeobotany-Palaeopalynology, University of Liège, Belgium; [3] Centre for Protein Engineering, University of Liège, Belgium; [4] Center for Biodiversity Theory and Modelling, USR CNRS 2936, France

Cyanobacteria are a morphologically diverse phylum, with their first occurrence dating from the Precambrian. Oxygenic photosynthesis appeared in this group during the same geological period. Several publications have established, without any doubt, that plastids (both primary and complex) form a monophyletic ensemble emerging from Cyanobacteria. However, the exact position of plastids within Cyanobacteria is still uncertain, with several recent papers leading to very different hypotheses. Here we present a phylogenomic analysis of the origin of plastids. Our study takes advantage of all the available genomes and thus represents the best taxonomic sampling seen so far: 140 genomes of Cyanobacteria, 101 genomes of plastids and 27 outgroups taken in Melainabacteria and Chloroflexi. It esults in an analysis using state-of-the-art methods (e.g., orthology assessment using USEARCH and rthoMCL, phylogenetic inference using CAT and CAT-GTR models) based on more than 160 protein alignments totalizing over 20,000 unambiguously aligned amino acids. To confirm our results, we performed gene jackknife inferences and gene reconciliation analyses on the same dataset. We expect that out approach accounts for potential phylogenetic artefacts due to changes in the evolutionary process having occurred when the guest cyanobacterium became an endosymbiont and eventually a plastid. Meanwhile, we improve the phylogeny of Cyanobacteria per se, notably because of the presence of Melainabacteria in our dataset.

BIOSTRATIGRAPHIC AND CHEMOSTRATIGRAPHIC CONSTRAINTS OF THE MBUJI-MAYI SUPERGROUP (MESO-NEOPROTEROZOIC AGE), DEMOCRATIC REPUBLIC OF CONGO.

Blaise K. Baludikay[1], Andrey Bekker[2], Daniel Baudet[3], Jean-Yves Storme[1], Emmanuelle J. Javaux[1]

[1]Palaeobiogeology, Palaeobotany, Palaeopalynology, Department of Geology, B18, University of Liege, 4000 Liège, Belgium; [2] Department of Earth Sciences, University of California, Riverside, Riverside, CA, 92521, USA; [3] Earth Sciences Department, Royal Museum for Central Africa, Tervuren, Belgium.

The Mbuji-Mayi Supergroup is a sedimentary sequence unaffected by regional metamorphism [1]. It was deposited between 1174 ± 22 Ma and ca. 800 Ma in the intracratonic failed-rift SMLL “Sankuru-Mbuji-Mayi- Lomami- Lovoy” basin [2] which extends from SE to NW between Katanga and Kasai Provinces. And overlies the Mesoproterozoic Kibaran Belt Supergroup (in the eastern part of SMLL basin) while in the Western part, where we focused our work, it rests unconformably upon Archean Dibaya Granitic Complex [3]. The amygdaloidal basaltic pillow lavas (948 ± 20 Ma) overlie the Mbuji-Mayi Supergroup, at the confluence of Mbuji-Mayi and Sankuru rivers [4]. Lithostratigraphically, this Supergroup consists in two distinct successions: a lower siliciclastic sequence (~500m) of BI Group and an upper carbonatic sequence (~1000m) with stromatolitic build-ups and black shales of BII Group

[2]. Our own and previous sedimentological observations [5] indicate facies ranging from subtidal, low-energy stromatolitic environments to overlying intertidal to supratidal evaporitic settings of lagoon and sabkha.

Here we present data on microfossil diversity and carbon isotope chemostratigraphy from the Kanshi, Lubi and Kafuku drillholes. The well-preserved and diverse assemblage of acritarchs and filamentous forms includes prokaryotes and eukaryotes, and is similar to other coeval assemblages described worldwide outside of Africa. The presence of the acanthomorph acritarch *Trachyhystrichosphaera aimika* is significant as it is indicative of the late Meso- to early Neoproterozoic age elsewhere, and is reported for the first time in Central Africa. So far, 56 species belonging to 31 genera were identified, dramatically increasing the previously reported diversity [6, 7]. Chemostratigraphy based on $\delta^{13}C_{carb}$ values for 290 samples, records, for the BI Group, predominantly negative values down to -8 to -9 ‰ VPDB with few samples having more positive, up to +3 ‰, values. Although the siliciclastics-rich sediments in the lower part of the BI Group likely record early diagenetic signal, carbonates in the upper part of the BI Group show similar patterns in both the Lubi and Kafuku drill cores with the sharp fall from +1 to +3 ‰ values to -8 to -7 ‰ and recovery back to +1 ‰ values over 40 to 70 m of section. The BII Group shows a less dramatic rise from -1 ‰ to +4 to +5 ‰ over more than 150 m of section. These large-scale variations differ from the steady-state carbon cycle of the late Mesoproterozoic [8] and are typical of the early Neoproterozoic record [9].

References: [1] Raucq, 1957, RMCA annals, 8, 18, 427pp. [2] Delpomdor et al., 2013b, Palaeogeog. Palaeoclimat. Palaeoecol. 389, 35–47. [3] Cahen, 1954, Palaeont. 56, 217-253. [4] Cahen et al., 1984, Press.Oxford, 512pp. [5] Delpomdor et al., 2013d, J. of Afr. Earth Sciences 88, 72–100. [6] Maithy, 1975, The Paleobotanist 22, 2, 133-149. [7] Baudet, 1983, Geol. J., 22, 121-137. [8] Bartley & Kah, 2004, Geology, 32, 129-132. [9] Halverson et al., 2010, Prec. Res., 182, 337-350.

CARBONACEOUS MATERIAL CHARACTERIZATION OF THE 3.2 GA MAPEPE FM, FIG TREE GROUP, BARBERTON GREENSTONE BELT, SOUTH AFRICA (BARB 5 DRILL CORE, ICDP PROJECT, CRADLE OF LIFE): NEW INSIGHTS FROM MICRO RAMAN SPECTROSCOPY ANALYSIS

Jean-Yves Storme[1], Emmanuelle J. Javaux[1] and the ICDP “Cradle of Life” team

[1]Palaeobiogeology, Palaeobotany, Palaeopalynology, Department of Geology, B18, University of Liege, 4000 Liège, Belgium.

Raman spectra of carbonaceous material (CM) from 79 samples of the BARB 5 drill core (ICDP project, Cradle of Life) were used to characterize thermal maturity, metamorphic grade and metamorphic temperature that have affected rocks of the middle Mapepe Formation (Fig Tree Group, BGB, South Africa). Raman analyses were performed with a Renishaw In via Raman spectrometer coupled to a Leica DM 2500 confocal microscope and with an Ar-ion-50 mW monochromatic 514.5 nm as laser source. Laser excitation was adjusted to an on-sample intensity of ca. 2mW (measured with a Coherent Lasercheck Analyser) and focused through a 50x objective to obtain a 1-2 µm spot size. Acquisitions were obtained with an 1800/mm grating with an air cooled (-70°C) 1024x256 pixel CCD array detector. This method enabled a 2000 cm^{-1} spectral detection range. Beam centering and Raman spectra calibration were performed daily on Si-Al microprocessor chip with a characteristic Si raman band at 520.5 cm^{-1}. Spectra were manipulated within Wire 3.4™ software. Point analysis measurements were made in static mode (fixed at 1150 cm^{-1}), spectra were collected from 10 different points in each sample and each spectra was acquired at 1x10 s running time. Peak parameters (G, D_1, D_2, D_3, D_4-bands; FWHM-D_1, FWHM-D_2; I_G, I_{D1}, I_{D2}, I_{D3}, I_{D4}; A_G, A_{D1}, A_{D2}, A_{D3}, A_{D4}) were obtained by fitting spectra (2-10 spectra by sample) with mixed Lorentzian-Gaussian curves.

Two peaks characteristic of disordered CM were observed in the samples. The G bands is located ~1592 ± 4 cm^{-1} (n=544; ±2σ) and results from in plane vibrations in ordered graphite. The D bands (D for disordered) is located ~1351 ± 2 cm^{-1} (n=544; ±2σ). The presence of well-developed D_3 and D_4 bands with D_1 band that is more intense than G band (FWHM-D_1 < 70 cm^{-1}) are indicative of rather poorly ordered CM that is typically encountered in lower greenschist-facies. Thermal maturity of CM was evaluated by comparing FWHM-G with G-position. The values fall in the range of those of the ~1.9 Ga Gunflint chert, ~2.7 Ga Tumbiana Fm or ~3.5 Ga Strelley Pool and Apex cherts which indicate that samples have experienced sub-greenschist to lower greenschist facies metamorphism. Another Raman thermal maturity "proxy" consisting in the relation between A_{D1}/A_G and I_{D1}/I_G ratios, which vary systematically with increasing metamorphic grade in metapelites, shows that the CM studied has a crystallinity equivalent to that of the chlorite-zone shales corresponding to lower greenschist facies or less. A tentative geothermometry based on 544 analysis is also proposed for the Mapepe Formation. Four different geothermometers involving R_1, R_2, R_{A1}, R_{A2} parameters were investigated giving a range of mean temperature evolving from 210°C to 355°C. This range of temperature is in line with the temperature expected for a lower greenschist-facies metamorphism.

Even if all these Raman characterization parameters describe above do not allow to elucidate the origins of CM, the parameter FWHM-D_1 plotted against I_{D1}/I_G ratio could, however gives some information about the precursor carbonaceous material of the sample. The values obtained for the Mapepe Formation could be compared to those of the Tumbiana Fm, Strelley Pool Fm and Apex chert but are different from those of the Gunflint chert.

References
Sforna et al., 2014 ; Lepot et al., 2013 ; Bower et al., 2013 ; Rahl et al., 2005 ; Tice et al., 2004 ; Beyssac et al., 2003 ; Jehlicka et al., 2003 ; Beyssac et al., 2002 ; Toulkeridis et al., 1994 ; Wopenka and Pasteris, 1993 ; ICDP « Cradle of Life » team, http://www.icdp-online.org/projects/world/africa/barberton/details/

BURIAL AND EXHUMATION DURING ARCHEAN SAGDUCTION IN THE EAST PILBARA GRANITE-GREENSTONE TERRANE, AUSTRALIA

François Camille[1,2], Philippot Pascal[1], Rey Patrice, Rubatto Daniela

[1]IPGP, now [2]Palaeobiogeology, Palaeobotany, Palaeopalynology, Department of Geology, B18, University of Liege, 4000 Liège, Belgium

Archaean granitic domes and intervening greenstone basins are often interpreted in terms of sagduction, a process which corresponds to the gravitational sinking of surficial greenstone covers into narrow belts and coeval exhumation of deeper granitic crust into broad domes. Alternatives models that can account for the regional dome and basin pattern include fold interferences and extensional metamorphic core complexes. In the attempt to distinguish between these various models we investigate the flow path of crustal particle in a typical Archaean terrane.

In the East Pilbara craton (Western Australia), the Warrawoona greenstone belt and adjacent Mount Edgar granitoid dome are particularly well preserved and exposed. In order to provide quantitative constraints on crustal particle's flow paths followed by rocks from greenstone-granite pairs in the East Pilbara craton, we conducted a multidisciplinary study – structural, metamorphic, geochemical, geochronological and numerical – of the 3.5-3.2 Ga old Mount Edgar high-grade rocks.

Garnet-bearing metasediments and metabasalts collected along the SW and SE rims of the Mount Edgar Dome show higher pressure but lower temperature of equilibration (0.9-1.1 GPa and 450-550°C) than enclaves collected in the core of the dome (0.6-0.7 GPa and 650-750°C). In situ oxygen isotope analysis and U-Pb dating of zircons from the enclaves indicate a metasedimentary origin ($\partial^{18}O \sim 13‰$) for the protolith and a metamorphic age of 3313 ± 5 Ma. In addition, monazites included in garnet from the SW dome margin yield an age of 3443 ± 5 Ma. The monazite ages suggest that an older metamorphic cycle occurred only 30 Ma before the main amphibolite facies event. The P-T-t data support fast, gravity-driven tectonics, where sedimentary rocks were buried to lower crustal conditions, metamorphosed and exhumed back to the surface during a cycle lasting only a few million years. Such a crustal flow is hard to reconcile with metamorphic core complexes and fold interferences. In contrast, results of forward thermo-mechanical modelling confirm that during sagduction upper crustal rocks are buried then exhumed in a few million years recording P-T-t evolutions similar to those deduced from thermobarometry and geochronology of the Mount Edgar region.

Our numerical experiments show a large range of possible apparent geothermal gradients during sagduction, including low apparent geothermal gradients that are similar to those proposed for Archaean and modern subduction. The wide range of gradients obtained in our sagduction modelling (*i.e.* 10-45°C/km) is in disagreement with the distinction between sagduction and subduction based on high (> 25°C/km) versus low (12-15°C/km) geothermal gradients, respectively. Moreover, we argue that mid-pressure and high-temperature mineralogical assemblages that are commonly interpreted as collision can also be produced during sagduction. Indeed, sagduction and subduction/collision can generate similar thermobarometric paths. Thereby, petrology and apparent geothermal gradient don't seem sufficient to discriminate between contrasting Archaean geodynamical frameworks.

CORRELATED MG-ZN ISOTOPE FRACTIONATION IN ARCHEAN KOMATIITIC LAVA-FLOWS

N. Mattielli[1,*], P. Haenecour[1,2] , G. Hublet[1] And V. Debaille[1]

[1]Laboratoire G-Time, Université Libre de Bruxelles (*correspondence : nmattiel@ulb.ac.be) ; [2]Laboratory for Space Sciences, Washington University in St. Louis, St. Louis, USA.

The Mg and Zn isotopic compositions of the mantle and the mechanisms governing Mg and Zn isotope fractionation during partial melting or fractional cristallization or mantle metasomatism are not fully resolved. Komatiites representing high-degree partial melts presumably formed by plumes hotter than the modern hot spots, make them extremely useful for addressing questions relevant to (early) mantle melting and heavy stable isotopes.

The present study reports high-precision MC-ICP-MS measurements of Zn and Mg isotopic compositions in whole rocks and mineral separates from Fred's Flow and Theo's Flow, two thick Archean differenciated flows (2.7 Ga) located in the Abitibi greenstone belt (Munro Township, Canada). Fred's Flow has a komatiitic affinity, and is classified as Al-undepleted type, whereas Theo's Flow has a Fe-rich tholeiitic affinity and is classified as Al-depleted type. Their geographical relationship and ages suggest that they are genetically related.

The entire profiles for each flow (whole rocks) display a narrow range of δ^{66}Zn values (0.23 d-units) with a weighted mean of +0.29‰. However, noticeable variations in δ^{66}Zn are observed between lithological units: spinifex and gabbroic units are characterized by slightly lower δ^{66}Zn (down to +0.28±0.04‰) when the cumulate units show enrichments in heavy Zn isotopes (δ^{66}Zn up to +0.55±0.05‰). The same trends and profiles are observed from the δ^{26}Mg data, with even stronger variations. The δ^{26}Mg results range from -0.36±0.05‰ (in the gabbroic unit) up to +0.21±0.02‰ (in the UB cumulate units).

Zn isotopic compositions in mineral separates vary on a large range of 1.6 d-units. Chromites show especially strong enrichments in light Zn isotopes, relative to the silicates. Olivine, clinopyroxene and plagioclase exhibit smaller isotopic fractionations with respect to each other, but are characterized by contrasted δ^{66}Zn values in agreement with enrichment in heavy Zn isotopes in minerals with lower Zn coordination.

The present study strengthens correlations between Zn and Mg isotopes both influenced by modal mineral abundances and inter-mineral fractionations.

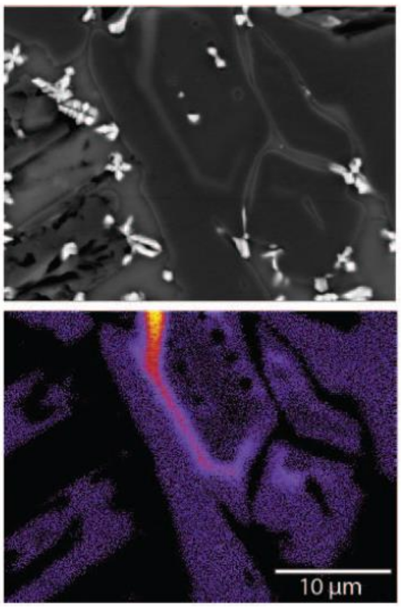
VERY HIGH NI OLIVINE IN A PORPHYRITIC COSMIC SPHERULE

M. S. Huber[1], S. Goderis[1,2], V. Debaille[1], and P. Claeys[1].

[1]Vrije Universiteit Brussel, Earth System Science, Dept. of Chemistry, BE-1050 Brussels, Belgium, matthew.huber@vub.ac.be; [2]Ghent University, Dept. of Analytical Chemistry, Krijgslaan 281 – S12, BE-9000 Gent, Belgium.

Cosmic spherules are dust particles of extraterrestrial origin that are melted during entry into Earth's atmosphere. The flux of such particles to Earth is approximately 40,000 tons per year [1]. Cosmic spherules typically have either glassy or quench textures. Over 1000 cosmic spherules and micrometeorites have been recovered from Widerøfjellet, Sør Rondane Mountains, Antarctica [2]. These cosmic spherules have a variety of textures and compositions. A porphyritic cosmic spherule with an anomalous olivine has been found amongst the recovered cosmic spherules. The sample was embedded in epoxy and polished, with the resulting surface being mapped by electron microprobe and scanning electron microscope (SEM). The SEM images revealed a compositional zone in one of the large olivine crystals, which was revealed by electron microprobe to have 10.95 wt. % NiO, and a composition of (Fe0.17, Mg1.59, Ni0.24)SiO4 (Figure 1). The surrounding olivine contains on average 2.6 wt. % NiO. The crystal structure was examined by Raman spectroscopy and determined to be consistent with olivine. High NiO abundances in olivine of cosmic spherules are sometimes associated with ablation spherules; however, the depletion of volatile elements suggests that this is not the case for this spherule [3]. To determine how such high percentages of NiO could be possible in a cosmic spherule, the MELTS program was used to model melting of precursors. Models used a range of 2000-1000 K to simulate total melting of chondritic precursors, with compositions taken from literature (i.e. [4]). High percentages of NiO were found to occur in olivine when melting an ordinary chondrite and allowing recrystallization in low redox conditions (Figure 2). The model also predicts low masses of crystallization of spinel (magnetite) prior to the crystallization of olivine, which is consistent with the petrographic observation of spinel crystals overgrown by olivine. The Ni-olivine zone is likely the result of changing crystallization conditions of the local melt. As can be seen in Figure 2, at the onset of crystallization of orthopyroxene, the Ni abundance of olivine temporarily increases. This is due to Mg preferentially entering orthopyroxene rather than olivine, resulting in Ni being more compatible with olivine for this period of crystallization.

References: [1] Maurette M. et al. 1991. *Nature, 351,* 44-47.
[2] Huber M. S. et al. 2014. 45th Lunar and Planetary Science Conference. Abstract #2108.
[3] Cordier C., van Ginneken M., and Folco L. 2011. *MAPS*, *46*, 1110-1132. [4] Jarosewich E. 1990. *Meteoritics, 25,* 323-337.



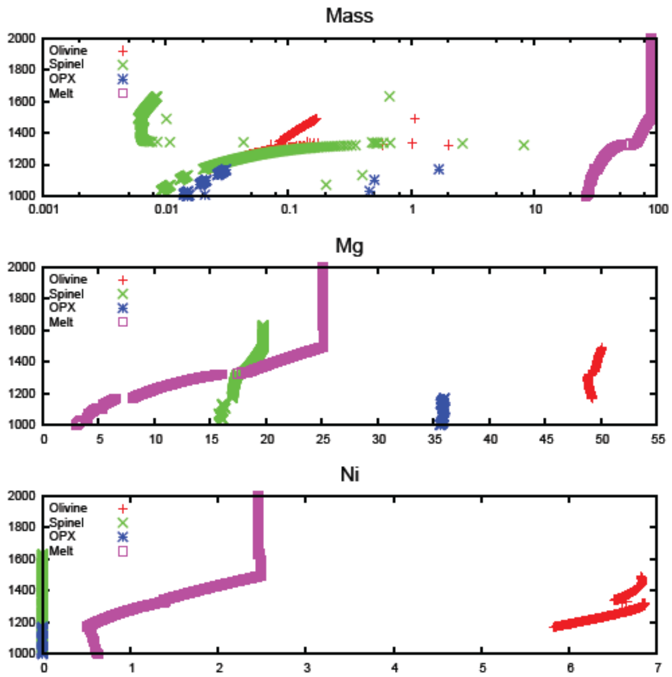


Figure 1 (left): Top: SEM image of olivine in porphyritic cosmic spherule showing zone of high NiO. Bottom: Microprobe map of NiO in same sample. Yellow colors are highest abundance. The maximum measured NiO in this sample is 10.95 wt. % NiO.

Figure 2 (right): Results of MELTS model of melting ordinary chondrite. Top: Mass of crystallizing phases. Note logarithmic X scale. Middle: Abundance of Mg in each. Bottom: Abundance of Ni in each phase.

CHRONOLOGY OF DIFFERENTIATION AND MAGMATIC ACTIVITY IN 4-VESTA USING 26AL-26MG MODEL AGE.

G. Hublet[1], V. Debaille[1], Q-Z. Yin[2],

[1]Département des Sciences de la Terre et de l'Environnement, Universite Libre de Bruxelles, CP 160/02, 50, Av. F.D. Roosevelt, 1050 Brussels, Belgium ; [2]Department of Geology, University of California, Davis, CA 95616

Eucrites and diogenites are igneous rock belonging to a magmatic meteorite series: Howardite-Eucrite-Diogenite (HED) widely believed to have come from the asteroid 4-Vesta. Short lived 26Al-26Mg isotopic system was developing on these achondrites to study the chronology of differentiation and magmatic activity on this asteroid.

In this study, mineral separation was realized on three basaltic eucrites, three cumulative eucrites and three diogenites. 26Al-26Mg internal isochron obtained show that basaltic eucrites are formed during a magmatic activity between ~4564Ma. The cumulative eucrites are formed deeper in the crust and cool down slowly until ~4560Ma. Finally, the diogenites formed after the complete extinction of the 26Al and can be date precisely with this Al-Mg isotopic system. Considering 26Al was homogeneously distributed in the solar system [1, 2] and a chondritic precursor for Vesta, model ages can be obtained for these achondrites by regressing 27Al/24Mg– δ26Mg* data. The bulk δ26Mg* value of the solar system at present day used in this study to anchor the isochron is the value of non-CAI-bearing chondrite [1, 3]. The model age obtained for the basaltic and cumulative eucrites suggested a common source for the two types of eucrite differentiated from this chondritic reservoir around ~4565.3 Ma. In opposition, model age cannot be calculated for diogenites suggesting a more complex history for formation and evolution of diogenite and their parental magma.

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FORMATION OF THE IIE NON-MAGMATIC IRON METEORITES

N. Van Roosbroek[1], L. Pittarello[2], V. Debaille[1], Ph.Claeys[2].

[1]Laboratoire G-Time, Université Libre de Bruxelles, B-1050 Brussels, Belgium ; [2] Earth System Sciences, Vrije Universiteit Brussel, B-1050 Brussels, Belgium.

Introduction: Iron meteorites can be divided into magmatic and non-magmatic (NMIM) groups based on chemical trends [1]. The magmatic irons rarely contain silicate inclusions and they are supposed to represent the cores of differentiated asteroids. The NMIM contain silicate inclusions and cannot be directly related to core formation as they show elemental trends that cannot be explained by fractional crystallization alone [2]. The IIE irons, a group of NMIM, possess a wide variety of silicate inclusions, ranging from large chondritic clasts to smaller molten feldspar-rich globules [3]. The diversity of features observed in the silicate inclusions of this group makes it difficult to constrain their formation history.
Silicate inclusions: To gain more insights into the IIE formation process, silicate inclusions from Mont Dieu II (MD II) [4] and Netschaëvo IIE were examined. The silicate inclusions of MD II possess a chondritic mineralogy and contain relict chondrules. Major element analysis, oxygen isotopic analysis ($\Delta^{17}O = 0.71 \pm 0.02$ ‰) and mean Fa and Fs molar contents ($Fa_{15.7 \pm 0.4}$ and $Fs_{14.4 \pm 0.5}$) indicate a genetic link with the H-chondrites. Netschaëvo silicates show a porphyritic texture dominated by larger clusters of olivine and pyroxene set in a fine-grained groundmass consisting of smaller hopper olivine crystals and quenched residual material. The Fa and Fs molar contents of the primary (preserved) grains ($Fa_{14.3 \pm 0.3}$ and $Fs_{14.7 \pm 0.1}$) and the oxygen isotopes ($\Delta^{17}O = 0.57$ ‰ [5]) are in the same trend as the H-chondrites but do not strictly overlap.

Formation: An impact formation model is proposed for both meteorites. In the case of MD II, this impact probably took place early on in the formation of the solar system, as indicated by the $^{40}Ar/^{39}Ar$ age of 4536 ± 59 Ma, on an H-chondrite parent body. The impact of Netschaëvo happened later on, around 3.7 Ga [6]. Although it was suggested that Netschaevo originated on a different parent body [7], different impact conditions and heterogeneity of the parent body could also explain the differences observed in Fa and Fs molar contents and oxygen isotopes between both meteorites.

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CHEMICAL COMPOSITION OF PRIMITIVE ACHONDRITES: CLUES FOR UNDERSTANDING THE EARLY DIFFERENTIATION PROCESSES OF THEIR PARENT BODIES.

Y. Hidaka[1, 2], N. Shirai[2], A. Yamaguchi[3], 4, M. Ebihara[2], and V. Debaille[1]

[1]Laboratoire G-time, Université Libre de Bruxelles, Belgium ; [2]Department of chemistry, Tokyo Metropolitan University, Japan; [3]National Institute of Polar Research, Japan; [4]Department of Polar Science, School of Multidisciplinary Science, Graduate University for Advanced Sciences, Japan.

Basaltic partial melting and Fe-Ni-S eutectic melting processes have been considered as the main processes of early differentiation of asteroids. We have determined lithophile and siderophile element abundances of primitive achondrites to investigate the early differentiation processes of their parent bodies. Primitive achondrites have lost chondritic texture, but still display chondritic compositions. However, they show a wide variety of rare earth element abundances that is difficult to explain by simple basaltic partial melting process. The relationship between incompatible trace element (Th) and Na, Al and K abundances is also difficult to explain by a single process. Concerning the siderophile element composition, we performed model calculation to consider what type of partial melting could have affected primitive achondrites. Model calculations indicate that W/Re, Mo/Co and other elemental ratios of primitive achondrite metals are difficult to produce by Fe-Ni-S eutectic melting. These results clearly show that early differentiation processes in the solar system bodies were much more complex than previously thought.

METAMORPHISM IN THE EH CHONDRITE PARENT BODY RECORDED BY MINOR ELEMENTS IN ACCESSORY OLIVINE.

Seann McKibbin, Lutz Hecht, Hermann Terryn, Philippe Claeys

Earth System Sciences, Vrije Universiteit Brussel, B-1050 Brussels, Belgium

EH chondrite meteorites formed in a reducing part of the Solar Nebula leading to abundant metallic Fe and pyroxene stabilised by low (FeO+MgO)/SiO2. In unequilibrated EH3 chondrites, a range of oxidation states are in fact indicated by variable FeO in silicates. However, on approach to equilibrium during metamorphism, near complete reduction of Fe occurs along with production of silica by reduction and extraction of Fe from pyroxene. This results in consumption of olivine by petrologic type EH4/5 according to Mg2SiO4 + SiO2 = Mg2Si2O6 and suggests that olivine in EH chondrites could be an indicator of metamorphic grade. Following previously suggested classification schemes, we have investigated olivine from eight EH3-4 chondrites by electron micro-probe analysis (A-881575, A-882059, ALHA-77295, EET87746, Sahara 97079, Y-691, Y-74370, and Y-791790 from the National Institute of Polar Research, the Meteorite Working Group, and the Royal Belgian Institute of Natural Sciences). Average minor element contents of olivine are generally correlated across all meteorites. Olivine from A-882059, Y-74370 and Y-791790 are distinguished by much lower average concentrations of Fe, Cr and Ti (latter below detection limit) and somewhat lower Ca, Al and Mn. Because new grain growth by dissolution-reprecipitation reactions is not possible due to consumption of olivine during metamorphism, concentration differences are likely to reflect pre-existing concentrations, or diffusion of cations through the olivine lattice. Results are consistent with diffusion of multivalent elements Fe, Cr and Ti to attain low equilibrium concentrations. Average Al contents are not well correlated with other elements, perhaps indicating slow diffusion of this tetrahedrally (rather than octahedrally) sited element. Minor elements in olivine records the duration of metamorphism in the EH parent body, and that Y-74370 and Y-791790 are among the most metamorphosed olivine-bearing EH chondrites.

GEOCHEMISTRY OF ARCHEAN MAFIC AMPHIBOLITES FROM THE AMSAGA AREA, WEST AFRICAN CRATON, MAURITANIA: WHAT IS THE MESSAGE?

Fatima El Atrassi[1]*, Vinciane Debaille[1], Nadine Mattielli[1], Julien Berger[2]

[1]Laboratoire G-Time, Université Libre de Bruxelles, ULB, Belgium ; *Corresponding author : Fatima.El.Atrassi@ulb.ac.be; [2] Géosciences Environnement Toulouse (GET), Université Paul Sabatier, Toulouse, France

While Archean terrains are mainly composed of a TTG (Tonalite-trondhjemite-granodiorite) suite, more mafic lithologies such as amphibolites are also a typical component of those ancient terrains. Although mafic rocks represent only ~10% of the Archean cratons, they may provide key evidence of the role and nature of basaltic magmatism in the formation of the Archean crust as well as the evolution of the Archean mantle.

This study focuses on the Archean crust from the West African Craton in Mauritania (Amsaga area). The Amsaga Archean Crust mainly consists of TTG and thrust-imbricated slices of mafic volcanic rocks, which have been affected by polymetamorphic events from the amphibolite to granulite facies.

Our main objectives aim to the identification of the mafic lithology origin and a better understanding of their role in the continental crust emplacement.
Our petrological observations show that these amphibolites have fine to medium granoblastic and nematoblastic textures. The amphibolites are dominated by amphibolite-facies mineral assemblages (mainly amphibole and plagioclase), but garnet and clinopyroxene occur in a few samples.
Two groups are distinct in their geochemical characteristics (major and trace elements), although both have tholeiitic basalt composition. The first group show LREE-enriched patterns and negative Nb-Ta anomalies. The second group is characterized by near-flat LREE patterns and flat HREE patterns. This second group clearly shows no Nb-Ta anomalies.

The first group could be related to arc-like basalts, as it is many similarities with some Archean amphibolites probably formed in a supra-subduction zone, for instance the volcanic rocks from the southern edge of the Isua Supracrustal Belt.
On the contrary, the second group has a MORB-like signature which is more unusual during the Archean. Different scenarios will be discussed regards to the Archean geodynamics.

WHEN DID PLATE TECTONICS BEGIN?

Vinciane Debaille[1], Craig O'Neill[2]

[1.] Laboratoire G-Time, Université Libre de Bruxelles, CP 160/02, 50 Avenue F.D. Roosevelt, 1050 Brussels, Belgium ; [2.] CCFS ARC Centre of Excellence, Department of Earth & Planetary Sciences, Macquarie University, Sydney, NSW, Australia, 2109.

The Earth is the only planet in our Solar System to currently show plate tectonics. On the other hand, it is often understood that plate tectonics could be an important requirement for allowing the development of complex life, by refurnishing the atmosphere as a consequence of important volcanism at the level of subduction zones, or by providing nutrients following enhanced erosion in mountains. Knowing if the Earth has always been in its present state is thus important to understand the apparition and development of life.

It is generally considered that the Archean (between 4 to 2.5 billion years (Gyr) ago) was much hotter than the present time, because of higher rates of internal heat production. A traditional view is thus that the mantle was convecting faster, resulting in plates moving faster at the surface of the Earth. However, we show that actually, when the viscosity of the mantle is lowered, as a consequence of higher temperatures, the viscous coupling between the crust and mantle located underneath is actually very low. The mantle was thus convecting faster, but with no consequence on the crust. We suggest that the predominant tectonic regime in the Archean was stagnant-lid regime, with sporadic subduction zones [1].

Several geochemical evidences support this suggestion. The first one the long mixing time of mantle isotopic anomalies or compositional heterogeneities, such as ^{142}Nd, ^{182}W, and platinum group elements [1-3]. In absence of plate tectonics, the mantle can still be convecting and poorly mixed. This could also explain why the martian mantle is poorly mixed, despite likely convecting. Second, some Jack Hills zircons could have crystallized from a mafic protolith that lasted 0.4 Gyr at the surface of the Earth. Such a long preservation time could not be reached with continuous plate tectonics. The Archean plate tectonics, being stagnant-lid plate tectonic with sporadic and short episodes of subduction, can reconcile long residence time and initiation of subduction zones. Modern plate tectonics, as observed today, could have started around or after 2.7 Gyr [1].

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THE SECULAR EVOLUTION OF ARCHEAN GRANITOIDS: EVIDENCE FOR THE ONSET OF "MODERN-STYLE" PLATE TECTONICS BETWEEN 3.0 AND 2.5 GA AGO

Oscar LAURENT[1,2,4], Hervé MARTIN[1], Jean-François MOYEN[3], Armin ZEH[4], Régis DOUCELANCE[1]

[1]Université Blaise Pascal, Laboratoire Magmas et Volcans, UMR6524-CNRS-IRD, Clermont-Ferrand, France ; [2]Present address : Université de Liège, Département de Géologie, Unité Pétrologie, Géochimie Endogène et Pétrophysique, Liège, Belgium ; [3]Université Jean Monnet, Département de Géologie, UMR6524-CNRS-IRD, Saint-Étienne, France ; [4]Goethe Universität, Institüt für Geowissenschaften, Facheinheint Mineralogie und Petrologie, Frankfurt am Main, Germany

The end of the Archean aeon, i.e. the timespan between 3.0 and 2.5 Ga ago, was a period of fundamental change in many aspects of the geological record on Earth. In particular, it corresponds to a major shift in the global composition of the continental crust, witnessed in Archean cratons by a considerable diversification in both the nature and petrogenesis of granitoid rocks.

Crustal material older than 3.0 Ga is essentially made up of a bimodal association of felsic, low-K granitoids belonging to the tonalite–trondhjemite–granodiorite (TTG) suite, coexisting with mafic volcanic rocks (komatiites, tholeiitic basalts) and very subordinate reworking products (granites, detrital sediments). Geochemical variability of TTGs shows that they derive from the partial melting of hydrous mafic rocks in a wide range of pressures, ranging from 0.5 to 3.0 GPa. From a geodynamic point of view, this implies that several tectonic settings of crustal growth were simultaneously operating on Earth prior to 3.0 Ga, which is not comparable to the modern, global operation of plate tectonics.

In contrast, granitoids emplaced between 3.0 and 2.5 Ga are much more diverse and can be classified into four groups: (1) volumetrically-dominant TTGs, but in contrast to their older counterparts, their geochemistry is consistent with an origin only at pressures >1.5 GPa; (2) Mg-, Fe- and K-rich, metaluminous (monzo)diorites and granodiorites, referred to as sanukitoids s.l., which derive primarily from hybridization between mantle peridotite and a component rich in incompatible elements; (3) peraluminous and K-rich biotite- and two-mica granites, formed through melting of older crustal lithologies (TTGs and meta-sediments, respectively); and (4) hybrid high-K granites with mixed characteristics from the first three groups.

Moreover, the chronology of granitoid emplacement in late-Archean times follows a very specific two-stage sequence: (1) a long period (0.15–0.5 Ga) of intermittent TTG emplacement; (2) a shorter period (0.02–0.15 Ga) during which all other granitoid types were generated. We propose that this evolution reflects the succession of subduction and continental collision, which is supported by comparison with modern orogenic systems. Prior to 3.0 Ga, such an evolution is either absent, or takes place only very locally, whereas it is a characteristic feature of all Archeans cratons between 3.0 and 2.5 Ga. Therefore, this sequence may represent the first global subduction–collision (Wilson) cycle in the Earth's history and, in turn, the global initiation of "modern-style" plate tectonics.
These changes were globally the consequence of the Earth's cooling, which controlled a number of different parameters on a local scale (thickness, temperature, volume and rheology of the crust). This explains why the changes took place over a short timespan (~0.5 Ga) relative to the Earth's history, but at different times and with different characteristics from one craton to another. In addition, the initiation of modern-style plate tectonics by the end of the Archean likely had a major influence in global geochemical systems, including the oxygen and carbon cycles, therefore influencing the stabilization of an appropriate climate and promoting the development of life.

SURFACE LAVAS, MANTLE SOURCES, AND SULFUR ON MERCURY

Bernard Charlier[1], Olivier Namur[2], Max Collinet[1,3]

[1] Department of Geology, University of Liege, Belgium; b.charlier@ulg.ac.be; [2]Institut fur Mineralogie, Leibniz Universitat Hannover, Germany; o.namur@mineralogie.uni-hannover.de; [3]Department of Earth, Atmospspheric and Planetary Sciences, Massachusetts Institute of Technology, USA; collinet@mit.edu

The composition of lavas at the surface of Mercury is characterized by low Fe, high Mg and Si, and very high sulfur concentrations (~1-4 wt.% S; [1-2]). This is unique among terrestrial planets and understanding sulfur solubility and speciation on Mercury can help deciphering global differentiation processes of the planet. In this project, data obtained by MESSENGER using X-Ray Spectrometry (XRS) for surface composition of the Northern Volcanic Plains (NVP) and older Intercrater Plains and Heavily Cratered Terrains (IcP-HCT; [1,3]) are used as starting compositions for crystallization experiments. Pressure ranges from 1 atm to 30 kbar, temperature from 1200 to 1600°C, and oxygen fugacity conditions from IW to IW-8.

Near-liquidus low- to medium-pressure experiments contain silicate melt, few forsterite crystals and several immiscible metal melts: (1) a FeSi-rich melt; (2) a FeS-rich melt and (3) a CaMgS-rich melt. In Na- and S-free systems, the lavas are saturated in orthopyroxene instead of forsterite. The concentration of sulfur in the silicate melt at sulphide saturation correlates with oxygen fugacity conditions and is relatively low (~ 0.5 wt.%) at IW, increasing significantly at more reduced conditions (2-6 wt.% at IW-4 - IW-6, up to 10 wt.% at IW-8). High-pressure experiments are relatively similar and phase equilibria are used to identify multiple saturation points (melt-forsterite-hypersthene) for the NVP and IcP-HCT compositions and to constrain the mantle source and melting P-T conditions that produced the different types of lavas erupted at the surface. The effect of pressure and oxygen fugacity on the liquid metal-liquid silicate partitioning is also used to better constrain the global composition of the core and bulk silicate mantle of the planet.

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ATMOSPHERE/MANTLE COUPLING ON VENUS AND LONG TERM PLANETARY EVOLUTION.

Cédric Gillmann[1] & Paul Tackley[2]

[1] Observatoire Royal de Belgique; [2] ETH Zürich, Geophysics department

We propose to investigate the evolution of the atmosphere and surface conditions on Venus and how they are linked with mantle dynamics. The key point of the study is the interaction between mantle and atmosphere. Coupling occurs on one hand due to mantle degassing, releasing volatiles into the atmosphere, and on the other hand through surface conditions and surface temperature that provide a boundary condition for convection processes.

Thus, we focus on mechanisms that deplete or replenish the atmosphere: volcanic degassing and atmospheric escape. These processes are linked together to obtain a coupled model, using retroaction of the atmosphere on the mantle.

Two aspects of the atmospheric escape are taken into account. During early evolution, hydrodynamic escape is dominant. We use a model developed to take into account the linked escape of Hydrogen and Oxygen (Gillmann et al., 2009). A significant portion of the early atmosphere can be removed this way. For later evolution, we focus on non-thermal escape, as observed by the ASPERA instrument and modeled in various recent numerical studies. Post 4 Ga escape is low. Water escapes moderately, while we are not able to detect the present-day escape of CO_2.

The atmosphere is replenished by volcanic degassing. We use the advanced StagYY code (Armann and Tackley, 2012) for mantle dynamics to compute the evolution of the interior of Venus and corresponding volcanic output. Volatile fluxes are estimated for different mantle compositions and partitioning ratios.

We use a gray radiative-convective model for the atmosphere of Venus. By tracking the evolution of greenhouse gasses in the atmosphere (water and CO_2) we follow surface conditions and temperature over time. Our mantle convection code then uses this temperature as a boundary condition, which in turn affects mantle dynamics.

Our results show that we are able to obtain a Venus-like behavior for the solid planet, with resurfacing events constituting an efficient way of losing Venus' internal heat. We are also able to create evolutions leading to present-day conditions. CO_2 pressure seems unlikely to vary much over the history of the planet, only slightly increasing due to degassing. A late build-up of the atmosphere with several resurfacing events seems unlikely. On the other hand, water pressure is strongly sensitive to volcanic activity and varies rapidly leading to variations in surface temperatures of up to 200K. We observe a clear negative feedback of the atmosphere on volcanic activity, as higher surface temperatures lead to a stagnant or episodic lid convection and less melt production. On the other hand, a lower surface temperature seems to favor mobile lid convection. Mobilization of the upper layers occurs, which imply that our coupling is not complete without taking into account rehydratation of the mantle.

POTENTIAL SYNERGIES IN THE INFRARED TO RETRIEVE METHANE ON MARS USING EXOMARS TRACE GAS ORBITER INSTRUMENTS

S. Robert[1], S. Chamberlain[1], F. Daerden[1], A. Mahieux[1], L. Neary[1], I. Thomas[1], S. Viscardy[1], V. Wilquet[1], A.C. Vandaele[1]

[1] Belgian Institute for Space Aeronomy, 3 Ave Circulaire, B-1180 Brussels, Belgium

In preparation of the ExoMars Trace Gas Orbiter (TGO), an ESA/ROSCOSMOS mission to be launched in 2016, synergies between different instruments onboard the spacecraft are investigated. The challenge is to capture CH_4 information as close as possible to the surface, in view of better addressing the understanding, quantification or monitoring of sources and sinks.

Two instruments functioning in the infrared spectral range will be part of the payload: NOMAD and ACS. Both spectrometers will be described and their assets in the retrieval of methane will be presented.

Using ASIMUT-ALVL, a line-by-line radiative transfer code developed at IASB-BIRA, we test synergistic approaches to combine different spectral domains and different geometries. This seems necessary for an optimal exploitation of near surface information from the available data. A synthetic dataset of spectra was created for different scenarios based on the atmospheric conditions deduced from the Global Circulation Model, GEM-Mars.

The results of the retrieval procedure and the benefits of the synergies will be discussed.

EXPERIMENTAL MEASUREMENTS OF THE EFFECT OF AMMONIA ON THE TABILITY OF CLATHRATE HYDRATES, WITH TETRAHYDROFURAN AS A PROXY FOR METHANE, AND IMPLICATIONS FOR OUTGASSING ON TITAN

Vu, T.[1], **Gloesener, E.[2]**, Choukroun, M.[1], Ibourichene, A.[3], Hodyss, R.[1], Karatekin, Ö.[2], and Dehant, V.[2]

[1] Jet Propulsion Laboratory, Pasadena, CA, USA; [2] Royal Observatory of Belgium, Brussels, Belgium; [3] Ecole Normale Supérieure, Paris, France.

The short lifetime of methane in Titan's atmosphere (a few tens of millions of years) implies the existence of internal or surface reservoirs that would add constantly methane to the atmosphere. The contribution of an external source is unlikely and the total amounts of liquids detected on Titan's surface do not represent sufficient methane to sustain the atmospheric amounts over geological timescales. Another possibility is that methane could be trapped at depth on Titan in the form of clathrate hydrates within an icy shell above an ammonia-enriched water ocean.

In this work, we studied the stability of tetrahydrofuran (C_4H_8O, hereafter THF) clathrates in presence of ammonia in order to better constraint outgassing processes on Titan. THF forms structure II clathrates below 4.4ºC at atmospheric pressure with THF molecules occupying large cage. The dissociation temperature of THF clathrates over a wide range of ammonia concentrations (from 0 to 25 wt%) is determined, using a liquid nitrogen cooled cryostage coupled to a microscope and a Raman spectrometer, in order to generate a phase diagram for the H_2O-THF-NH_3 system. Our results suggest that the effect of ammonia on THF clathrates is the same as its effect on water ice. Indeed, ammonia lowers the dissociation point of THF clathrates whose the dissociation curve is equivalent to a liquidus with a eutectic point at -70ºC. On icy moons such as Titan where clathrates are likely involved in methane outgassing, the presence of small amounts of ihhibitors might be sufficient to trigger some partial dissociation and perhaps some outgassing into the atmosphere. However, further experiments are required to determine if these results can be applied to methane clathrates

GEOPHYSICAL CONSTRAINTS FOR THE 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. 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. 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, 2) the temperature profile in an liquid ocean considering high-pressure and -temperature thermodynamic properties of water (IAPWS), 3) the occurrence 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) the possible occurrence of a second, lower ocean at the ocean-mantle boundary by melting of the ice layer from below, 5) possible constraints for volcanism and thus crust formation at the ocean-mantle boundary depending on ocean thickness and planet mass

We assume that ocean worlds may be called habitable (Class III/IV habitats after Lammer et al., 2009, Astron Astrophys Rev 17, 181-249) if they have a liquid ocean layer (or restricted habitable with a high-pressure ice layer surrounded by two liquid water layers), plate tectonics (especially the occurrence 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.

DYNAMICS OF EXOPLANETARY SYSTEMS, LINKS TO THEIR HABITABILITY

Bolmont E.[1], Raymond S. N.[2], Selsis F.[2]

[1] Univ. Namur, Belgium; [2] Observatoire de Bordeaux

Our knowledge of planet dynamics, which was based on Solar System studies, has been challenged by the diversity of exoplanetary systems. Around cool and ultra-cool dwarfs, the influence of tides on the orbital and spin evolution of planets can strongly affect their climate and their capacity to host surface liquid water.

I will illustrate the role of tides and dynamics with the extreme case of planets orbiting around brown dwarfs. In multiple planet systems, the eccentricity is excited by planet-planet interactions. Planets are therefore heated up from the inside by the tidally-induced friction. This process can heat a habitable zone planet to such a level that surface liquid water cannot exist.

I will also talk about the newly discovered potentially habitable Earth-size planet Kepler-186f. Given the poorly estimated age of the system, the planet could still be evolving towards synchronization and have a high obliquity or be pseudo-synchronized with a zero obliquity. These two configurations would have a different effect on the climate of this planet.

NEWS FROM BELGIAN PLANET SEARCHES: SPECULOOS & TRAPPIST

Monika Lendl, Michaël Gillon, Emmanuël Jehin, Valérie Van Grootel

AGO Astrophysics Department, Université de Liège

In the context of the search for habitable planets, planets orbiting ultra-cool stars are of particular interest. Owing to their small and low-luminosity host stars, these systems are ideal targets for both, planet detection and the study of planetary atmospheres. Additionally the habitable zone is located close-in, in a region readily accessible for transit searches. The "Search for habitable Planets EClipsing ULtra-cOOl Stars" (SPECULOOS) survey will target the ~500 closest southern ultra-cool stars searching for transiting Earth-size planets in their habitable zone. I will describe the current status of the SPECULOOS project, and show results from a design study carried out with the "TRAnsiting Planets and PlanItesimals Small Telescope" (TRAPPIST). I will also present the future extension of the project to the northern sky with the telescope TRAPPIST-North that ULg will install next year in Morocco.

FROM VORTICES TO STREAM DOMINATED: PHASE CHANGE IN THE ATMOSPHERE DYNAMICS OF TIDALLY LOCKED TERRESTRIAL PLANETS WITH EARTH-LIKE INSOLATION

Ludmila Carone

KULeuven

Tidally locked terrestrial planets around M dwarfs are the prime targets for the investigation of habitability of exoplanets: M dwarfs are the most common stars in the solar neighborhood, M dwarfs' small size and coolness yield a favorable star-planet contrast for characterization (transmission spectra, secondary eclipse etc.) and, furthermore, the relative short orbital period (~1 month) of planets in the habitable zone around M dwarfs facilitate detection and detailed follow-up of potentially habitable planets.

Understanding habitability on such planets, requires, however, understanding the atmosphere and its dynamic that sets the stage for pressure-temperature profiles, cloud formation and chemical processes. We present here a suite of example simulations using our simplified 3D atmosphere model for tidally locked terrestrial planets. We will show that depending on the planetary parameters, in particular, the orbital period, different dynamical regimes are expected. For shorter period (Prot<10 days), the atmosphere is expected to be dominated by an equatorial jet, whereas for longer orbital period (Prot>10 days), the atmosphere becomes more and more vortices dominated, with one particular consistent feature at the east terminator. We will furthermore show how this change in dynamical regime is associated with changes in global circulation (important for cloud formation), surface winds and surface temperatures. The latter constrain surface liquid water and thus habitability.

THE ASTROMAP EU FP-7 PROGRAMME: A PREPARATORY STEP TO ASTROBIOLOGY IN HORIZON 2020.

C. Muller[1] and the ASTROMAP consortium

[1]B.USOC

ASTROMAP is a roadmapping EU FP-7 programme coordinated by CAB (Centro de Astrobiología, Spain). Participants are: European science Foundation, DLR (Germany), B.USOC and Instituto Nazionale di AstroFisica (INAF). EANA and the UKCA (UK Centre for Astrobiology are associated partners.

The main objectives are to identify the main astrobiology issues to be addressed by Europe in the next decades in relation with space exploration, identify potential mission concepts that would allow addressing these issues, identify the technology developments required to enable these missions, provide a prioritised roadmap integrating science and technology activities as well as ground based approach and mapping scientific knowledge related to astrobiology in Europe.

The programme, in the Space them, started in late 2012 and will have its final event in Brussels at the end of 2015, the methodology and the already achieved steps will be described. The current support to Astrobiology given by the HSO (Human Space and Operations) directorate of ESA since the beginning of the AURORA programme will also be described.

HOW LARGE ARE PRESENT-DAY HEAT FLOW VARIATIONS ACROSS MARS' SURFACE?

Plesa, Ana-Catalina [1], Tosi, Nicola [1,2], Grott, Matthias[1], Breuer, Doris[1]

[1] German Aerospace Center DLR, Berlin, Germany (ana.plesa@dlr.de); [2] Technical University Berlin, Berlin, Germany

The upcoming InSight (Interior exploration using Seismic Investigations, Geodesy and Heat Transport) mission, to be launched in 2016, will carry the first in-situ Martian heat ow measurement and provide an important baseline to constrain the present-day heat budget of the planet and, in turn, the thermal and chemical evolution of its interior. Currently, the Earth and the Moon are the only bodies on which in-situ surface heat flow measurements have been performed. Here, strong spatial variations of the surface heat flow are primarily caused by plate tectonics and the heterogeneous distribution of heat producing elements over the surface (e.g., the so-called Procellarum KREEP Terrane PKT on the lunar nearside). In the absence of plate-tectonics and large-scale geochemical anomalies, on Mars, surface heat flow is expected to vary less with geological location, being mainly influenced by variations in the thickness and HPE content of the crust [1], and by mantle plumes [2].
We have tested this assumption by running thermal evolution models for Mars in 3D spherical geometry [3]. In our calculations, we use a crust of fixed thickness with a north-south dichotomy in crustal thickness, a low conductivity compared to the mantle and enriched in radiogenic heat producing elements. Our results show that including compressibility e_ects, phase transitions and different core sizes, surface heat flow variations are mainly dominated by the crust contribution, unless the mantle viscosity increases more than three orders of magnitude with depth. In the latter case, heat flow variations due to mantle upwellings are ~8 mW/m2 relative to surface average and remain confined to limited surface regions (Fig. 1). Both surface heat flow variations on Mars obtained from numerical models and the heat ow measurement planned for the InSight mission will permit to address the question of a possible plume underneath Elysium and also to test the feasibility of present-day volcanism on Mars.

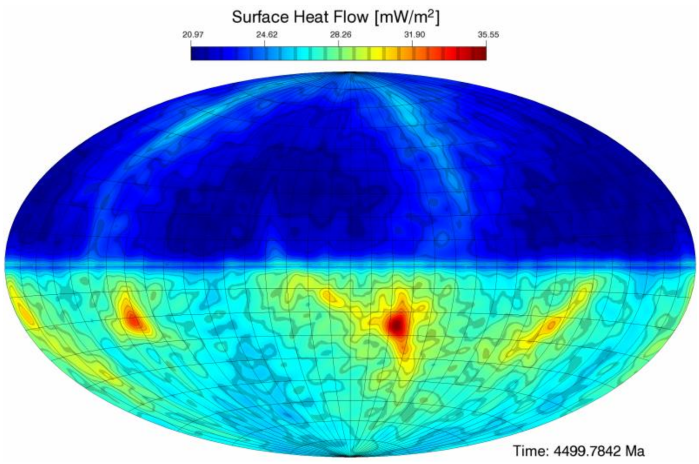

Figure 1: Surface heat flow variations after 4.5 Ga of thermal evolution.

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