Crustal Differentiation on Mars: A New View of the Red Planet Forty Years after Viking

November 11th 2016, RAS.

10-3.30 pm.

Professor John C. Bridges, Space Research Centre, University of Leicester j.bridges@le.ac.uk

Dr Susanne P. Schwenzer, School of Environment, Earth and Ecosystem Sciences, The Open University susanne.schwenzer@open.ac.uk

Forty years after the Viking mission landings on Mars in 1976, our view of Mars as an inactive, entirely basaltic planet has changed radically. Recent results from Mars Science Laboratory show localised silica enrichments and evolved igneous rocks within the clasts and fluvio-lacustrine sediments of Gale Crater. Many new martian meteorites are being identified and include evidence for magmatic differentiation. The martian meteorites also record hydrothermal alteration of the martian crust.

An objective of this meeting is to produce a review paper about our current state of knowledge on Mars magmatism and differentiation of the crust.

Keynote Speakers: Dr Ernst Hauber, DLR: 'The link between tectonic style and magmatism on the terrestrial planets: The case of Mars'

Dr Justin Filiberto, Southern Illinois University. 'Geochemistry of Martian Basalts with Constraints on Magma Genesis'

Dr Astrid Holzheid, University of Kiel. 'Basalt-CO2 interaction on Mars and Earth'

Dr Jens Frydenvang, Lawrence Livermore Laboratory. 'ChemCam analyses at Gale Crater: Silica Enrichment Processes'

The meeting will enable a focus on recent research including: 1. What igneous differentiation did Mars experience?

2. Did the ancient Mars environment experience chemical weathering and associated major compositional and mineralogical changes? This debate will be used to inform the ExoMars Rover landing site selection and also a better understanding of the past atmosphere losses and habitable conditions.

2. Ancient alluvial networks and the evidence for and implications of a northern ocean.

4. Communicate recent Mars science developments including Trace Gas Orbiter and Schiaparelli.

This will include a talk from Sue Horne, UKSA about UK planetary science options and activities.

Programme:

https://www2.le.ac.uk/departments/physics/people/johnbridges/Mars%20Meeting

Abstracts

#1. Compositional End Members in Gale Crater, Mars.

C. C. Bedford1, J. C. Bridges2, S. P. Schwenzer1, R. C. Wiens.3 1The Open University, Walton Hall, Milton Keynes, MK7 6AA (candice.bedford@open.ac.uk), 2 Space Research Centre, University of Leicester, Leicester, LE1 7RH. 3Los Alamos National Laboratory, Los Alamos, New Mexico, USA.

Geochemical data returned from the Mars Science Laboratory's *Curiosity* rover over 1296 sols, have revealed a previously unforeseen martian geochemical complexity. Before *Curiosity* landed in Gale Crater, Martian SNC meteorite studies [1] along with previous orbiter, rover and lander data showed Mars as being a predominantly basaltic planet with little magmatic differentiation [2]. But through using density contour plots of ChemCam observation point data alongside data derived from *Curiosity's* other instruments, Mars Exploration Rover (MER) *Spirit,* and shergottite meteorite compositions [3], 4 geochemical end members in Gale sedimentary and igneous morphological samples have been identified.

These end members are; an Fe-rich basalt similar to that observed at Gusev, a trachybasalt, an alkaline igneous source and a silica-rich source. The basalt is the dominant source composition. These sedimentary end members are thought approximately representative of an igneous source composition due to Mars' low chemical weathering rate [4] and therefore provide further evidence of evolved magmatic assemblages in the Ancient Noachian crust around Gale Crater.

References: [1] Bridges J. C. and P. H. Warren. 2006. *Journal of the Geological Society*. 163(2):229-251. **[**2] McSween H. Y. et al. 2009. *Science* 324:735-739. [3] Edwards P. H. *in rev.*. *Meteoritics and Planetary Science*. [4] Bibring, Jean-Pierre, Yves Langevin et al. 2006. *Science.* 312, no. 5772: 400-404.

#2. Small-scale volcanoes on Mars: distribution and types

Petr Brož (1) and **Ernst Hauber** (2)

(1) Institute of Geophysics ASCR, v.v.i., Prague, Czech Republic, Petr.broz@ig.cas.cz (2) Institute of Planetary Research, DLR, Berlin, Germany, Ernst.Hauber@dlr.de

The study of small, km-scale Martian volcanoes has been generally neglected until high-resolution imaging and topographic data became available. These data reveal a variety of shapes and morphological details in unprecedented detail. We can now investigate several types of small-scale volcanoes in various regions and determine their basic morphologic and morphometric properties. Our research suggests that scoria cones are present in Tharsis (Ulysses Colles), and inside Valles Marineris (Coprates Chasma), tuff rings and tuff cones in at least three different locations (Nepenthes/Amenthes region, Arena Colles and inside Lederberg crater), and that lava domes may exist in the highlands of Terra Sirenum. As scoria cones, tuff rings/tuff cones, and lava domes provide a record of magmatic degassing, magma-water interactions, and possibly the generation of evolved lavas on Mars, respectively, their investigation provides insights into different aspects of volcanism on Mars which were difficult to obtain in the past. The increasing recognition of morphological diversity of Martian volcanic landforms parallels the geochemical/mineralogical results obtained by rovers, which challenge the traditional view of a purely basaltic planet.

#3. Extensive Noachian fluvial systems in Arabia Terra: Implications for early Martian climate

J.M. Davis[1*], M. Balme[2], P.M. Grindrod[3], R.M.E. Williams[4], and S. Gupta[5]

[1]Department of Earth Sciences, University College London, UK [2]Department of Physical Sciences, Open University, UK [3]Department of Earth and Planetary Sciences, Birkbeck, University of London, UK [4]Planetary Science Institute, Tucson, Arizona, USA [5]Department of Earth Sciences and Engineering, Imperial College London, UK*Email: joel.davis.09@ucl.ac.uk

Valley networks are some of the strongest lines of evidence for extensive fluvial activity on early (Noachian; >3.7 Ga) Mars. However, their purported absence on certain ancient terrains, such as Arabia Terra, is at variance with patterns of precipitation as predicted by "warm and wet" climate models. This disagreement has contributed to the development of an alternative "icy highlands" scenario, whereby valley networks were formed by the melting of highland ice sheets. Here, we show through regional mapping that Arabia Terra shows evidence for extensive networks of sinuous ridges. We interpret these ridge features as inverted fluvial channels that formed in the Noachian, before being subject to burial and exhumation. The inverted channels developed on extensive aggrading flood plains. As the inverted channels are both sourced in, and traverse across, Arabia Terra, their formation is inconsistent with discrete, localized sources of water, such as meltwater from highland ice sheets. Our results are instead more consistent with an early Mars that supported widespread precipitation and runoff.

#4. ExoMars 2020 landing site characterisation

Peter Fawdon[1], Elliot Sefton-Nash[1,2], S.M.Turner[3], Peter Grindrod[1], Matt Balme[4], Sanjeev Gupta[5], John Bridges[3]

[1]Birkbeck, University of London, [2]European Space Agency, [3]The Open University, [4]Imperial College London, [5]University of Leicester.

One of the key objectives of the ExoMars 2020 rover mission is to look for past or present life on Mars. Consequently, the choice of landing site is vital to the mission. Since the start of the landing site selection process in 2014, when more than six sites were proposed, a UK team has been involved with the process, presenting two sites, and analysing several others. Now, only three sites for the ExoMars Rover remain in the shortlist: Aram Dorsum (UK-led), Oxia Planum, and Mawrth Vallis [1]. The down-selection to the 'final + backup' sites will take place in March 2017, and final selection in 2019. Aram Dorsum is dominated by an exhumed Noachian alluvial system, Oxia Planum is clay-bearing and may have deltaic deposits. Mawrth Vallis is clay-rich but of more uncertain origin.

Here we present an update on the landing site characterisation and selection process since the third discussion workshop at ESTEC in late 2015. Our focus is on the most recent results and conclusions from our continued efforts to understand the science potential at all sites, in addition to ongoing studies of engineering constraints and hazards. We present a brief summary of the scientific highlights of each site, as well as some of the challenges the various sites present.

#5. Geochemistry of Martian Basalts with Constraints on Magma Genesis

Justin Filiberto

Southern Illinois University, Department of Geology, Carbondale IL 62901 USA

Basaltic rocks analyzed in situ from MER Spirit and Opportunity and MSL Curiosity are more diverse in composition than the rocks represented by the Martian meteorites, which suggests that they may have tapped different source regions [1-4]. Surface rocks have more variable Si contents, and higher total alkalis than shergottites [1-4]. Surface rocks are also ancient while shergottites are young [4, 5]. Here, I will review what is known of the geochemical diversity of Martian magmas, and use the diversity of bulk chemistry and age to constrain the thermal and chemical evolution of the Martian interior.

Refs: [1] Treiman A.H. and Filiberto J. (2015) MaPS, 50. 632-648. [2] McSween H.Y. (2015) AmMin, 100. 2380-2395. [3] Edwards et al. (in review) MaPS. [4] Sautter et al. (2015) Nature Geosci, 8. 605-609. [4] Nyquist L.E. et al. (2001) Space Sci Rev, 96. 105-164. [5] Farley K.A. et al. (2014) Science, 10.1126/science.1247166. [6] Greely et al. (2005) JGR, doi:10.1029/2005JE002401.

#6. ChemCam analyses in Gale Crater, Mars – mapping the geochemical stratigraphy of Aeolis Mons, one laser-shot at a time.

Jens Frydenvang and the ChemCam team

Orbital detection of extensive hematite-, clay- and sulfate-bearing stratigraphic layers in the lower part of Aeolis Mons was the primary reason Gale Crater was selected as the landing site for the Mars Science Laboratory *Curiosity* rover. ~750 martian solar days (sols) after the Curiosity rover landed in Gale Crater in August 2012, and after driving more than 9 km, the Curiosity rover arrived at the first exposure of the basal layer of Aeolis Mons. This basal Murray formation is a thinly laminated lacustrine mudstone showing stratification down to the millimeter scale - supporting that the orbital spectral signatures arise from sedimentary layers deposited in a series of long-lived lakes extending into the early Hesperian time (Grotzinger et al., *Science, vol. 350,* 2015).

The chemical variations observed during our ascent of the Murray formation in the 700+ sols since first arriving at Aeolis Mons will be presented. While the Murray formation remains a primarily thinly laminated mudstone, a testament to the longevity of the ancient lacustrine activity in Gale Crater, large chemical variations are observed, pointing both to silicic volcanic activity during the period with lacustrine activity, and evidence of liquid water in the subsurface long after the lacustrine activity seized.

#7. Determining the Source Locations of Martian Meteorites: Non-Linear Unmixing Models in The VNIR.

J. K. Harris[1,2], and P. M. Grindrod[1,2]

[1]Dept. of Earth and Planetary Sciences, Birkbeck, University of London, UK, [2]Centre for Planetary Sciences at UCL/Birkbeck, London, UK. (jennifer.harris@ucl.ac.uk)

Martian meteorites represent the only samples of Mars available for study in terrestrial laboratories. However, these samples have never been definitively tied to source locations on Mars, meaning that the fundamental geological context is missing. This work aims to link the detailed geochemical analyses of martian meteorites to the geological evolution of Mars through quantitative non-linear mixture analysis of CRISM data. Three major constraints exist on possible source locations based on existing analysis of the martian meteorites: 1) their predominantly igneous nature, 2) their crystallisation and ejection ages and 3) their bulk mineralogy. We are combining broad geological and chronological filters with non-linear unmixing of CRISM data to link the bulk mineralogy of the meteorites to specific martian locales by: (1) identifying potential source craters, (2) applying VNIR models to these source craters, and (3) understanding the geological history of each site. Development of non-linear unmixing models is ongoing, but we have already compiled a database of all VNIR analyses of martian meteorites. By applying geological filters of age, crater size, latitude dependence and elevation, we have reduced the possible number of source locations from >200,000 to < 2700. We expect our non-linear unmixing models to reduce this number by a further one or two orders of magnitude.

#8. Carbonates and the Secondary Mineralogy of Mars: Meteorites And Experimental Studies

L.J. Hicks[1], J.C. Bridges[1], S.P. Schwenzer[2], M.A. Miller[3]

[1]University of Leicester, Space Research Centre, Dept. of Physics and Astronomy, LE1 7RH, UK, ljh47@le.ac.uk

[2]Open University, School of Environment, Earth and Ecosystem Sciences, MK7 6AA, UK

[3]Southwest Research Institute, San Antonio, TX 78228, USA

The physiochemical characteristics of martian carbonate deposits can help reveal past environmental conditions, including the compositions and partial pressure pCO_2 of the atmosphere and the T, pH, compositions of fluids. Here we describe meteorite studies and related experimental work to test the conditions of alteration that the martian crust experienced.

The nakhlite martian meteorites contain hydrothermal veins, the result of H_2O-CO_2-rich fluids from shallow subsurface ice-bearing rocks and the dissolution of the nakhlite olivines and feldspathic mesostasis [1]. Carbonates deposited at 150-200°C, followed by crystalline saponite and Al-rich ferric serpentine [2,3], and then a rapidly cooled metastable assemblage with poorly crystalline gel at ~50°C [1]. The Fe-rich carbonates deposited on the walls of olivine fractures, and within the mesostasis, with no discernible variation in chemical composition between the two settings [4]. The nine nakhlites have varying degrees of alteration, enabling relative distances from the fluid source to be determined, Lafayette being the closest. Martian carbonates have also been identified in the ALH 84001 meteorite [5], the Gusev landing site [6], and from orbit [7]. The recently discovered martian meteorites NWA 10416 and NWA 8159, contain alteration phases [8,9], but their martian origin remains to be established.

Using the Mars brines experimental apparatus at NASA Ames [10], mixtures of olivines, pyroxenes, and/or plagioclase were used in fluid-rock alteration experiments. The samples were immersed in purified water at 35 °C under a synthetic martian atmosphere for a 1 month and a 3 month experiment. The resulting alteration in the olivine (Fa_8) fractures are deposits of poorly crystalline Mg-rich silicate clays and carbonates (Mg1.7-4.4 Cc41-47 Sd0.0-0.6 Rh0 %), analogous to nakhlite secondary phases. This suggest that the martian meteorite alteration was rapid e.g. of 1-3 months duration.

[1] Bridges J.C. and Schwenzer, S.P. (2012), *Earth Planet. Sci. Lett.*, **359-360**:117-123. [2] Hicks L.J., et al. (2014), *Geochim. Cosmochim. Ac.*, **136**:194-210. [3] Changela H.G. and Bridges J.C. (2011), *Meteorit. Planet. Sci.*, **45**:1847-1867. [4] Hicks L.J. and Bridges J.C. (2015), *78th An. Meteorit. Soc. Meeting* (Abstract #5290). [5] Bridges J.C., et al. (2001), *Space Sci. Rev.*, **96**:365-392. [6] Morris R.V., et al. (2010), *Science*, **329**:421-424. [7] Ehlmann B.L., et al. (2008), *Science*, **322**:1828-1832. [8] Herd C.D.K., et al. (2016), *LPSC XLVII* (Abstract #2527). [9] Vaci Z., et al. (2016), *LPSC XLVII* (Abstract #2538). [10] Bullock M.A. and Moore J.M. (2004), *GRL,* **31**: doi:10.1029/2004GL019980.

#9. Early processes in planetary bodies: constraints from solar system basalts

Astrid Holzheid

Universität Kiel, Institut für Geowissenschaften, 24098 Kiel, Germany

When comparing the chemical compositions of the terrestrial planets and smaller differentiated asteroidal planetesimals we have to rely on basalts for comparison. Comparing basalts from Earth, Mars, Moon and Vesta, i.e. planets and planetesimals with FeNi-cores, yields: (1) SiO_2 and MgO concentrations cover only a small compositional range and (2) absolute Ni and Co contents as well as the Ni/Co ratios increase with the radius of the planet. The small differences in SiO_2 and MgO contents suggest a similar extent of fractionation, while the variations in absolute Ni and Co contents as well as Ni/Co ratios provide information of early processes within the planetary bodies. However, it is still unclear if Ni and Co contents in basalts from Earth, Mars, and Moon can be achieved solely by metal separation as conditions of core formation may also depend on other variables. But it is beyond doubt that eucrites show the very low Ni and Co contents expected from metal/silicate equilibration at low pressures.

#10. Goethite in Northwest Africa 8114

J. L. MacArthur1, J. C. Bridges1, L. J. Hicks1, G. M. Hansford1 and L. Paget1.

1Space Research Centre, Dept. of Physics & Astronomy, University of Leicester, LE1 7RH. jane@janemac.org

Martian regolith breccia NWA 8114 (a pair of NWA 7034) [1,2] was likely formed as a result of an impact event [3] which may have led to hydrothermal systems causing further alteration to it [4,5]. Our investigation of a goethite inclusion in a basaltic clast aims to determine if the goethite is of extraterrestrial origin and examines the role of water in the regolith evolution. D/H isotope analyses support the martian origin of the hydrated phases [6], and the majority of this water is suggested to be hosted by hydrous Fe oxides [7] such as maghemite, goethite, ferrihydrite [4,8], with a minor contribution from apatite.

Results and Discussion: The Fe oxide inclusion (Fig. 1b) is oxidized [9], and two veins of terrestrial Ca carbonate cross-cut it, therefore the Fe oxide formed earlier than the veins. XRD d-spacing peaks for the inclusion indicate goethite and were used to give unit cell dimensions (all in Å) of a=3.015±0.002, b=4.634±0.006, c=9.967±0.009 compared with standards a=2.99–3.048, b=4.559-4.641, c=9.854-10.065 [11].

EPMA data for the inclusion showed total oxide weights of 78.1% (FeO 71.8%, SiO_2 3.6%, MgO 0.6%, CaO 0.9%, NiO 0.9%, Al_2O_3 0.2%, TiO_2 0.1%), consistent with goethite. FTIR reflection data taken from an FTIR map of the clast shows a clear absorption peak at 3150 cm^{-1}, matching the synthetic goethite shown in [8] and distinguishing it from other hydrated iron oxides.

Given this textural evidence of the terrestrial veins cross-cutting the goethite, and the martian D/H isotope analyses [6], the goethite was most likely formed on Mars. This indicates the presence of a liquid in the regolith as it slowly cooled on Mars.

References: [1] Humayun M. et al. 2013. Nature 503, 513-516. [2] Santos A. et al. 2014. GCA 157, 56-85. [3] Hewins R. H. et al. 2014. Abstract #1416. 45th LPSC. [4] Gattacceca J. et al. 2014. GRL 41, 4859-4864. [5] Liu Y. et al. 2016. Abstract #1127. 47th LPSC. [6] Agee C. B. et al. 2013. Science 339, 780-785. [7] Muttik N. et al. 2014. Geophysical Research Letters 41, p. 2014GL062533. [8] Beck P. et al. 2015. EPSL 427, 104-111. [9] MacArthur J. et al. 2015. Abstract #2295. 46th LPSC. [10] MacArthur J. et al. 2016. Abstract #2916. 47th LPSC. [11] ICDD PDF-4/Minerals 2014 database, http://www.icdd.com Int. Centre for Diffraction Data

#11. Unravelling the degassing histories of the telluric planets using experimental rock-deformation alongside stable isotope geochemistry

Sami Mikhail, The Department of Earth and Environmental Sciences, School of Geography and Geosciences, Irvine Building, The University of St. Andrews, UK.

Michael J. Heap, Institut de Physique de Globe de Strasbourg (UMR 7516 CNRS, Université de Strasbourg/EOST), 5 rue René Descartes, 67084 Strasbourg cedex, France.

Paul K. Byrne, Planetary Research Group, Department of Marine, Earth, and Atmospheric Sciences, North Carolina State University, Raleigh, North Carolina, USA. (paul.byrne@ncsu.edu).

The chemistry of a planet's atmosphere is an archive of surface and subsurface processes, including volcanism, weathering, meteoric influx, and biological activity. Therefore, the chemistry of a planet's atmosphere can be used to constrain the history of its surface-interior exchange(s) over geological timescales. We focus on the noble gases because (1) more than 99% of a planet's noble gas inventory is found in its atmosphere and (2) these elements are unreactive (incompatible) and therefore preserve their primary origins (i.e. they're unaffected by secondary processing). Importantly, some noble gas isotopes are primordial (e.g. 36Ar, 130Xe) while others are the daughter products of long- and short-lived radionuclides from lithophile and volatile elements (e.g. 40K-40Ar, and 130I-129Xe). This means noble gases can be used to investigate the similarities and differences in the origin and history of the atmospheres enveloping Venus, Earth, and Mars. The role of rock deformation is to constrain the nature and viability of pathways that serve to allow fluids and melts to migrate through telluric lithospheres. This is a key consideration because the permeability of the lithosphere controls the ability of a planet to degas isotopes like 40Ar and 129Xe. We will show how the different surface temperatures of Venus, Earth, and Mars, alongside differences in the planet's surface gravitational acceleration (proportional to planets mass), can be combined to illuminate the geochemical evolution of the Martian, Terran, and Venusian atmospheres.

#12. Anaerobic utilisation of olivine by chemolithotrophic bacteria

Price, A.1; Pearson, V. K.1; Schwenzer, S. P.2; Olsson-Francis, K2. 1School of Physical Sciences, Open University, UK. 2School of Environment, Earth and Ecosystems Sciences, Open University, UK.

Nitrate-dependent iron-oxidising (NDFO) microorganisms make use of Fe(II) and nitrate compounds in a redox reaction, which yields energy for ATP synthesis. One known species, Pseudogulbenkiania sp. strain 2002, has been shown to conduct this process using only inorganic carbon sources. Here we test the feasibility of NDFO on Mars.

Bacterial strains (Pseudogulbenkiania sp. strain 2002 & Thiobacillus denitrificans) were cultured with crushed olivine or fayaltic glass granules (compositionally analogous to typical martian mineralogy) as a source of ferrous iron, in nitrate-containing media with inorganic carbon sources (CO_2 & $NaHCO_3$). Pseudogulbenkiania sp. strain 2002 and Thiobacillus denitrificans were able to grow using olivine as an Fe(II) source, and the addition of an organic carbon source (acetate) improved growth. Thiobacillus denitrificans was also able to grow on fayalitic glass; whereas Pseudogulbenkiania sp. strain 2002 required the addition of acetate to grow.

The utilisation of Mars-relevant ferrous minerals by these microorganisms in the absence of organic carbon suggest that NDFO metabolism has potential for viability on Mars.

#13. Ground truthing orbital clay mineral observations with the APXS onboard Mars Exploration Rover Opportunity

C. Schröder1, R. Gellert2, S. VanBommel2, B.C. Clark3, D.W. Ming4, D.W. Mittlefehldt4, A.S. Yen5

1Biological and Environmental Science, Faculty of Natural Sciences, University of Stirling, Stirling FK9 4LA, UK, christian.schroeder@stir.ac.uk; 2University of Guelph, Guelph, Ontario, Canada; 3Space Science Institute, Boulder, CO, USA; 4NASA Johnson Space Center, Houston, TX, USA; 5Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA

NASA's Mars Exploration Rover Opportunity has been exploring ~22 km diameter Endeavour crater since 2011. Its rim segments predate the Hesperian-age Burns formation and expose Noachian-age material, which is associated with orbital Fe^{3+}-Mg-rich clay mineral observations [1,2]. Moving to an orders of magnitude smaller instrumental field of view on the ground, the clay minerals were challenging to pinpoint on the basis of geochemical data because they appear to be the result of near-isochemical weathering of the local bedrock [3,4]. However, the APXS revealed a more complex mineral story as fracture fills and so-called red zones appear to contain more Al-rich clay minerals [5,6], which had not been observed from orbit. These observations are important to constrain clay mineral formation processes. More detail will be added as Opportunity is heading into her 10th extended mission, during which she will investigate Noachian bedrock that predates Endeavour crater, study sedimentary rocks inside Endeavour crater, and explore a fluid-carved gully. One of the potential landing sites for ESA's ExoMars rover is Noachian-age Oxia Planum where abundant Fe^{3+}-Mg-rich clay minerals have been observed from orbit, but the story will undoubtedly become more complex once seen from the ground.

References: [1] Wray J.J. et al. (2009) Geophys. Res. Lett. 36, L21201. [2] Noe Dobrea E.Z. et al. (2012) Geophys. Res. Lett. 39, L23201. [3] Arvidson R.E. et al. (2014) Science 343, 1248097. [4] Fox V.K. et al. (2016) Geophys. Res. Lett. 43, 4885–4892. [5] Clark B.C. et al. (2016) Am. Mineral. 101, 1515-1526. [6] Mittlefehldt D.W. et al. (2016) LPSC 47, 2086.

#14. Martian subsurface water-rock interaction(s) – from meteorites to ExoMars

Schwenzer1, S. P., Bridges2, J. C., Bedford1, C., Steer1,3, E. D., Melwani Daswani1,4, M.

1The Open University, Milton Keynes, UK. Susanne.schwenzer@open.ac.uk, Candice.Bedford@open.ac.uk; 2University of Leicester, j.bridges@le.ac.uk; 3University of Nottingham, Elisabeth.steer@nottingham.ac.uk; 4University of Chicago, melwani@uchicago.edu.

The magmatic rocks in the subsurface of Mars were subject to a variety of alteration mechanisms. The highest alteration temperatures were reached in hydrothermal systems. Magmatic hydrothermal systems could have provided acidic conditions and contained other volatile species supplied by the magma; and impact-generated hydrothermal systems could have re-heated large and deep reaching parts of the Martian crust, altering the target rocks but without additional volatiles from a magma. The low-temperature water rock reactions are represented in diagenetic processes, which on Mars are governed by a geothermal gradient of about 13 °C/km and below freezing surface temperatures. Besides the chemistry of the alteration site itself, and the possible addition of volatiles, the abundance of water is another critical factor. High water to rock ratios can lead to extensive leaching, and low water to rock ratios to the formation of microenvironments and steep chemical gradients. This leads to a wide variety of alteration environments, studied in the nakhlite and ALH84001 Martian meteorites, in situ on Mars through the Opportunity and Curiosity rovers, and from orbit by the CRISM and Omega instruments. Findings range from clay minerals (nontronite, montmorillonite) to salts (Ca-sulfates). Understanding alteration pathways is possible through thermochemical modelling, which allows the assessment of unobservable parameters: temperature during formation, element (nutrient) pathways and the energy balance.

References: Bridges, J. C. et al. (2015) JGR, 120: DOI: 10.1002/2014JE004757. CARTER, J. (2013) JGR, 118, 831–858. EHLMANN, B. L. et al. (2013) Space Science Reviews, 174: 329–364. MELWANI DASWANI, M. et al. (2016) MAPS DOI: 10.1111/maps.12713. SCHWENZER, S. P. and KRING, D. A. (2013) Icarus, 226: 487–496. ZOLOTOV, M. Y. and MIRONENKO, M. V. (2016) Icarus, 275: 203–220.

#15. ExoMars Schiaparelli & TGO – status update

Colin Wilson (Dept. of Physics, Oxford University) & ExoMars Schiaparelli & TGO teams

On 19 October 2016, all being well, TGO will successfully perform its Mars Orbit Insertion manoeuvre and the Schiaparelli lander should arrive gently at the surface of Mars. Data will have been acquired during descent from the AMELIA investigation, and descent images should be obtained by the DEscent CAmera (DECA). At the surface, meteorological measurements should be obtained during at least two sols of surface operation by the DREAMS payload, including (for the first time ever at Mars) measurements of electric fields. The surface operations timeline includes measurement campaigns throughout the diurnal cycle, with extended campaigns at sunrise at sunset, and during early afternoon when dust devil activity is most prevalent. The Schiaparelli operations, and any initial results, will be discussed.

#16. The influence of salt composition on the entombed microbial community within the deep sub-surface Boulby Mine

Peter Woolman1, Victoria Pearson1, Thomas Edwards2, Stephen Summers3, Karen Olsson-Francis1

1 The Open University, Walton Hall, Milton Keynes, MK7 6AA 2 Israel Chemicals Group, Boulby Mine, Loftus, Saltburn-by-the-Sea, Cleveland, TS13 4UZ 3 Heriot-Watt University, Edinburgh Campus, EH14 4AS

Halophiles are often proposed as a model organism for analogue studies of potential martian life [1] because atmospheric conditions on Mars are such that liquid water could only exist in the form of highly concentrated brines [2]. While no known terrestrial halophiles could survive on the present day surface of Mars, environmental conditions are believed to have been more hospitable to life in the distant past, and, as the conditions worsened, organisms analogous to halophiles would have been able to survive for longer than others [3].

There is now strong evidence that microbes, and specifically haloarchaea, can survive inside halite crystals for millions of years [4, 5]. This raises the potential for the preservation of ancient martian life in subsurface halite crystals, either as broken cellular components or even as viable cells [6]. While martian salt deposits are known to exist, they are unlikely to consist of NaCl in the concentrations found on Earth [7]. It is important to assess the impact that different ion compositions have upon long-term entombment of halophiles in salt crystals, in order to determine the value of these martian sites as potential refuge for life.

In this study samples of halite, potash and the interface between them were sampled from Boulby Mine, Yorkshire. ICP-MS was used to determine the ionic composition of the rocks, while T-RFLP was used to investigate the microbial community. This work was carried out with the expectation that the large changes in K^+ from potash to halite would cause similarly large changes in the microbial communities, but this was not observed to be the case. Very small changes in Ca^{2+} concentration, however, were able to cause large changes in community composition. XRD shows that this calcium is almost exclusively $CaSO_4$. The known evaporitic deposits on Mars primarily consist of sulphate minerals [7]. Determining why the $CaSO_4$ in Boulby Mine influences the microbial community will answer important questions about the long term survival of subsurface halophiles and the viability of martian salt deposits as a place to look for extinct or extant life.

References: [1] Orwig, J. Transactions American Geophysical Union, 2014 [2] Tosca, N.J., A.H. Knoll, and S.M. McLennan, 2008. [3] Fendrihan, S., M. Musso, and H. Stan-Lotter, Journal of Raman spectroscopy : JRS, 2009. [4] Gramain, A., et al., Environmental microbiology, 2011. [5] Jaakkola, S.T., et al., Environ Microbiol, 2015. [6] Fendrihan, S., et al., Re/views in environmental science and bio/technology (Online), 2006. [7] Barbieri, R. and N. Stivaletta, 2011.