GeoFutures 2024: Planetary Geoscience

14 - 15 November 2024

ABSTRACT BOOK

Royal Astronomical Society

The Geological Society

Welcome to GeoFutures 2024

'GeoFutures' is the forward-looking conference series from the Geological Society, aimed at bringing together diverse audiences to find solutions to the challenges of the 21st century.

In 2024, we are delighted to be partnering with our courtyard neighbours, the Royal Astronomical Society, to bring **GeoFutures 2024: Planetary Geoscience** to life.

We also want to thank our supporters, both the Geological Society of America and the Science & Technology Facilities Council (STFC), for their contributions towards this meeting.

Our programme committee had members from all three societies, crafting the varied programme of presentations you see here. We hope you enjoy it!

The Geological Society

UKRI Science and Technology Facilities Council

THE GEOLOGICAL SOCIETY OF AMERICA®

Royal Astronomical Society

Thursday 14th November		
1000-1010	Welcome	Natasha Stephen *(Geological Society)*
1010-1100	**Keynote:** MESSENGER, BepiColombo, and beyond: what's next for Mercury?	Jack Wright *ESA & Open University*
SESSION ONE – THE INTERSECTION OF MISSIONS & SAMPLE SCIENCE		
1100-1115	3D and 2D clast analysis of Apollo 17 core sample 73002: insights into the Light Mantle dynamics and regolith reworking	Giulia Magnarini *Natural History Museum*
1115-1130	Numerical Simulations for the Hydrothermal Evolution of Early Mars & Habitability Computations	Christou Evangelos *University of Glasgow*
1130-1145	Investigating the Apollo 16 regolith in preparation for surface missions	Stephanie Halwa *University of Manchester*
1145-1230	*Coffee Break*	
SESSION TWO – FUNDING & INTERNATIONAL COLLABORATIONS		
1230-1245	ESA's Vulcan Facility; Derisking Space Exploration using Planetary Surface Analogues - opportunities for collaboration	Kamini Manick *European Space Agency*
1245-1300	UKRI and the Science & Technology Facilities Council	Jenny Hiscock *Science & Technology Facilities Council*
1300-1315	An introduction to planetary geoscience at NASA (title tbc)	Nick Lang *NASA*
1315-1330	The RAS: Supporting Planetary Science	Robert Massey *Royal Astronomical Society*
1330-1430	*Lunch*	

SESSION THREE – SAMPLE COLLECTION, CURATION & ANALYSIS		
1430-1445	Correlative analyses of Sulphur-bearing Serpentine in Carbonaceous Chondrites	Niamh Topping *University of Leicester*
1445-1500	The origin of Main Group pallasites explored using trace element analysis	Ana Pagu *University of Oxford & Geological Society*
1500-1515	Micrometeorites: New collections, their possibilities and problems	Penny Wozniakiewicz *University of Kent*
1515-1530	In-situ high-precision isotopic analysis of extra-terrestrial materials at nanoscale	Mahesh Anand *Open University*
1530-1545	Eucrite Metamorphism in Three Dimensions: A Compositional and Textural Investigation of Pyroxene Clouding with Scanning and Transmission Electron Microscopy	Jennifer T. Mitchell, *University of Minnesota*
1545-1615	*Coffee Break*	
SESSION FOUR – COMMUNITY UPDATES & DISCUSSION		
1615-1630	An Update on the UK Planetary Forum	Mark Nottingham *UK Planetary Forum*
1630-1645	The UK Cosmochemistry Analysis Network	Katie Joy *UKCAN, University of Manchester*
1645-1700	The UK's National Meteorite Collection	Sara Russell *Natural History Museum*
1700-1715	The UK Fireball Alliance: building an all-sky UK meteor observatory	Luke Daly *UK Fall, Natural History Museum*
1715-1745	Lightning session for poster presenters (3 mins each)	
1745-1930	*Poster Session & Drinks Reception*	

Friday 15th November 2024		
0900-0930	*Registration opens*	
0930-1020	**Keynote:** EnVision Venus: Understanding why our closest neighbour is so different	Philippa Mason *Imperial College London*
1020-1105	What does it take to get involved in space missions? A panel discussion with *those in the know…*	Various
1105-1135	*Coffee break*	
SESSION FIVE – REMOTE SENSING & SOLAR SYSTEM EXPLORATION		
1135-1150	Investigating the age and structure of the Ina IMP on the Moon	Lionel Wilson *Lancaster University*
1150-1205	Determining the Principal Azimuths of Valles Marineris: A Comparative Analysis of Bezier Spline and GIS Techniques	Dan James *Citizen Scientist*
1205-1220	The burial and exhumation of Mount Sharp, as recorded by the fracture sets at Maria Gordon Notch, Gale crater, Mars.	Steve Banham Imperial College London
1220-1350	*Lunch*	
SESSION SIX – MISSION SCIENCE: MISSION HIGHLIGHTS, KEY UPDATES, NEW MISSION PROPOSALS		
1350-1405	Water, water, everywhere: A mineralogical tale of the Bennu asteroid	Sara Russell *Natural History Museum*
1405-1420	Enceladus: Sampling the Plume	Mark Burchell *University of Kent*
1420-1435	Half a Glass of Sunshine	Luke Daly *University of Glasgow*

SESSION SIX – MISSION SCIENCE: MISSION HIGHLIGHTS, KEY UPDATES, NEW MISSION PROPOSALS (CONTINUED)		
1435-1450	Hidden in plain sight? On the challenges of detecting molecular markers for life in typical planetary samples.	Steve Larter *University of Calgary*
1450-1505	Planetary seismology: from Mars to the Moon and beyond	Tom Pike *Imperial College London*
1505-1520	Phobos' Origin: A Ground-Truthing Investigation through Laboratory Analysis of Meteorites.	Emelia Branagan-Harris *University of Oxford & NHM*
1520-1550	*Coffee Break*	
1550-1605	Nanogeoscience approaches for Mars Sample Return: maximising the outputs of analytical sample science using analogues of Jezero crater sedimentary rocks	Keyron Hickman-Lewis *Birkbeck, University of London*
1605-1620	Reconstructing the stratigraphic architecture at the apex of a Martian sedimentary fan system at Gnaraloo Bay, Jezero crater, Mars.	Robert Barnes *Imperial College London*
1620-1635	What Depositional Processes and Paleoenvironments Formed the Layered Sulphate Unit in Gale Crater, Mars?	Amelie Roberts *Imperial College London*
1635-1650	Geochemical and isotopic constraints on the petrogenesis of Plio-Quaternary alkaline rocks from the middle atlas (Morocco): Implications for mantle metasomatism	Said Haidatte *Université Chouaib Doukkali El Jadid, Morocco*
NEXT STEPS & PUBLICATIONS		
1650-1705	Get involved: Planetary Science at the Geological Society & Opportunities for Publishing Your Research	Thomas Harvey, Marrisa Lo, Ana Pagu, *The Geological Society*
1705-1720	Looking Forward & Close	Natasha Stephen *The Geological Society*
1730	*End of conference*	

Poster Presenters

The Fate of Venusian Chlorine	Katherine Bormann *University of Oxford*
Development of a Correlative Workflow in Preparation for the Return of Mars Samples	Francesca Willcocks *University of Leicester*
Icebergs on Early Mars	Alberto Fairén *Astrobiology Center, Madrid, Spain*
Fluvial and Lacustrine Processes on Mars and their relevance to exploring Mars' Habitability.	Nisha Gor *Open University*
Carbon in CI Chondrites – Comparing Ivuna to Sample Return Missions	Pippa Lewis *University of Cambridge*
The Fluvial History of Noachis Terra	Adam Losekoot *Open University*
Advancing Karst Exploration with Remote Sensing and Artificial Intelligence: A Framework for Earth and Planetary Karst Systems	Luka Vucinic *Glasgow Caledonian University*

ORAL ABSTRACTS (in programme order)

Thursday 14th November 2024

KEYNOTE: MESSENGER, BepiColombo, and beyond: what's next for Mercury?

Jack Wright[1,2]

[1]European Space Agency
[2]Open University

3D and 2D clast analysis of Apollo 17 core sample 73002: insights into the Light Mantle dynamics and regolith reworking

Guilia Magnarini[1], Mitchell T. M.[2], Grindrod P. M.[1], Bell S. K.[3,4], Joy K. H.[3] , Eckley S. A.[5,6], Zeigler R. A.[6] , Schmitt H. H.[7], Shearer C.[8] , and the ANGSA Science Team

[1]Natural History Museum
[2]University College London
[3]University of Manchester
[4]Straum Reservoir AS
[5]Jacobs – JETS, Astromaterials Research and Exploration Science Division
[6]NASA Johnson Space Centre
[7]University of Wisconsin Madison
[8]University of New Mexico, Lunar and Planetary Institute

The Light Mantle landslide deposit in Taurus-Littrow Valley, on the Moon, was one of the geological targets of the Apollo 17 mission, as scientists wanted to understand how it formed and which mechanism was responsible for its long runout. A cylindrical sample of the top 70 cm of the Light Mantle deposit, made up of two sections, was collected by Apollo 17 astronauts and kept closed for almost 50 years. As part of the NASA Apollo Next Generation Sample Analysis (ANGSA) initiative, the sample has been recently opened and it has been made available for study. Before being dissected for analysis, the sample has been scanned using state-of-the-art X-ray computed tomography (XCT) technique. In this study, we used the XCT dataset of sample 73002 and, for the first time on a lunar core sample, we conducted a 3D analysis of the clast size distribution. Our analysis shows that the upper 5 cm corresponds to reworked regolith. Moreover, we used 2D thin sections and showed the presence of clast-cortex aggregates (CCAs), which are considered evidence of granular flow dynamics during the Light Mantle emplacement. This study shows the potential of the novel information that can be obtained from lunar core samples.

Numerical Simulations for the Hydrothermal Evolution of Early Mars & Habitability Computations

Christou Evangelos[1], Lydia Hallis[1], Luke Daly[1], Martin Lee[1]

[1]University of Glasgow

The habitability of Mars has not been decisively established yet. Quantitative analyses and models for the ancient or present bioenergetic potential on Mars are scarce. Water – rock interactions enduring in long-lived hydrothermal settings on Earth yield appreciable quantities of chemical nutrients that support microbial species under hydrothermal conditions. Through this perspective, ancient Martian hydrothermal systems should be thoroughly investigated and sampled. This research focused on simulating the hydrothermal evolution of the Martian crust and the habitability potential of its aqueous environments via correlative numerical models and microscopy analyses (SEM, TEM, EPMA, APT) of Martian meteorite samples. The presented thermodynamic and fluid-mechanic simulations explore thoroughly the evolution and duration of impact-induced or magmatic-induced hydrodynamic activity in the Martian crust from the pre-Noachian to the late Amazonian period (present). These thermodynamic results were then used as input parameters and conditions in further computations for Martian water – basaltic rock reaction pathways and in determining their bioenergetic yield (habitability). Conclusively, quantitative habitability assessments are presented based on the energy – chemical nutrient availability and the thermodynamic constraints that subsequently determine the Martian subsurface as habitable or uninhabitable for hypothetical lithotrophic microbial species.

Investigating the Apollo 16 regolith in preparation for surface missions

Stephanie Halwa[1], K.H. Joy[1], R. Tartèse[1], M. Nottingham[2], M. Almayrac[1], and S. K. Bell[3]

[1]University of Manchester
[2]University of Glasgow
[3]Stratum Reservoir, Sandnes, Norway

Observations show postulated enhanced volatile concentrations stored in the regolith within permanently shadowed regions (PSRs) at the lunar poles. The European Space Agency is building the PROSPECT experiment package that will target a lunar south polar region to determine the abundance and isotopic composition of these volatiles. The regolith in this area is dominated by highland crustal material, likely similar to Apollo 16 (A16) samples. In preparation for PROSPECT, it is important to understand impact mixing processes in highland regolith, and how this has affected the volatile budget of 'typical' ice-free feldspathic regolith. We studied 25 samples from various depths (up to 60 cm) within 4 double drive tubes, from central and southern areas of the A16 landing site. Mineralogy was analysed using an FEI QUANTA 650 scanning electron microscope with QEMSCAN software. Mineral phases in 5 thin sections were analysed for major element abundances using a Cameca SX100 electron microprobe. Noble gas abundances of soil sub-split samples were acquired using a Thermo Scientific™ HELIX multi-collector noble gas sector mass spectrometer. Initial findings show that stratigraphic horizons vary across the area with no local correlation, even for cores 50 m apart, with an abundance of exotic material from non-proximal regions. However, the depth of the uppermost reworked layer is consistently 10 - 13 cm across the landing site. Noble gas isotopic concentrations and agglutinate abundances indicate the regolith in the central landing site may be more well mixed with depth than previously thought. The implications show that it may be complex to unravel the series of impact events in similar highland terrains, such as the south polar region. Enhanced noble gas concentrations which may be measured by PROSPECT could indicate a new source of volatiles that is extra-lunar/not related to regolith processing. This work is funded by STFC.

The UK Space Agency

Craig Brown[1]

[1]UK Space Agency

ESA's Vulcan Facility - Derisking Space Exploration using Planetary Surface Analogues; opportunities for collaboration

May Martin[1], **Kamini Manick[1],** Florence Wilkinson[2], Sophie Griffith[3], Roy Franks[4], Joseph McQuaide[5]

[1]European Space Agency
[2]University of Manchester
[3]Oxford University
[4]Imperial College London
[5]University College London

The European Space Agency's Vulcan Facility, located at ECSAT, Oxfordshire, houses Moon, Mars, and asteroid analogue samples, with the primary aim of using these simulants to derisk exploration technology development activities. Recent research projects include: the creation of lunar south pole-specific simulants designed for use in rocket plume-surface interaction experiments, to understand the potential damage caused to infrastructure by landing spacecraft on the Moon; and the creation of MARSIE (Mars Advanced Regolith Simulant for Iron Extraction) to further develop and test methods for extracting resources from the local regolith. The Vulcan facility also houses analytical equipment for sample characterisation, and provides support and future planning for sample curation activities within ESA and around Europe. Our secondary aim is to support and further develop curation activities (including defining standards and procedures) in preparation for long-term storage, handling, and analyses of returned extraterrestrial samples to Europe. Future planned research includes: development of more high-fidelity, landing site-specific simulants for the Moon and Mars to support future mission development; design and creation of a Phobos simulant to support the Mars Moon eXploration (MMX) mission; investigation of how shocked minerals affect in situ resource utilisation (ISRU) processes and traversability of lunar regolith; and potential 3D printing and radiation shielding tests with high-fidelity lunar simulants. In addition, the Vulcan facility has assisted ESA's Luna Facility (based at EAC, Cologne) with choosing the most suitable lunar dust simulant for its 'Dust Chamber'. Fieldwork campaigns, including the ExoMars Field Trials, were planned and implemented in collaboration with the Vulcan facility, and the resulting data and field samples are curated as part of Vulcan's collection. Please contact the authors of this abstract should you require information about Vulcan's analogue collection (many samples are available for loan) or for potential collaborative projects.

UKRI and the Science & Technology Facilities Council

Jenny Hiscock[1]

[1]Science & Technology Facilities Council

An Introduction to planetary geoscience at NASA

Nick Lang[1]

[1]NASA

The RAS: Supporting Planetary Science

Robert Massey[1]

[1]Royal Astronmical Society

Correlative analyses of Sulphur-bearing Serpentine in Carbonaceous Chondrites

Niamh Topping[1], John Bridges[1], Leon Hicks[1], Lukas Petera[2,3], Christopher Allen[4,5,6], Mohsen Danaie[4,5], David Hopkinson[4,5] Jinseok Ryu[4,5], Lucy Blase[1], and Hitesh Changela[2,7]

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[5]DLS
[6]University of Oxford
[7]University of New Mexico

CM and CI carbonaceous chondrites experienced extensive aqueous alteration on their parent bodies [Brearley 2006; Suttle, 2021]. Notably, the serpentinization of ferromagnesian silicates resulted in the formation of phyllosilicate-rich matrices, constituting ~80 vol% of the CMs and the CIs [King 2015, 2022; Garvie, 2021; Ito, 2022] and where the primary phase is serpentine [McSween, 1987]. Sulphur has a range of valence states (S2- to S6+) and can be used to infer about redox conditions during parent body alteration; e.g. Fe-sulphides are already used as an indicator of alteration conditions by analysing Fe to S ratios [Schrader, 2016; Singerling, 2020]. We have identified sulphur-bearing serpentine in several CM and CI chondrites, and have adopted a series of correlative techniques to characterize this phase and to better understand a potential link between serpentine formation, the sulphur cycle and related redox conditions. Samples underwent SEM-BSE imaging and EDS, and TEM lift-outs prepared for high-resolution, aberration-corrected (S)TEM analyses at ePSIC, DLS: HRTEM imaging for lattice spacing measurements, high-resolution EDS, and 4DSTEM with EDS for simultaneous acquisition of structural and compositional data. The I18 microfocus beamline, DLS, was used for S-K edge XANES to determine the sulphur valencies to try and constrain the location of sulphur in the serpentine structure. We conclude that sulphur, as S2-, is structurally incorporated into serpentine via partial replacement of O2- in OH-, and S6+ is trapped as SO42- ions in the hexagonal vacancies, and that during aqueous alteration a S-rich fluid formed from the oxidation of primary sulphides, constituting part of the wider alteration pathway during which sulphur was sequestered in serpentine. This multi-technique approach demonstrates the importance of both structural and compositional information for detailed interpretation of mineral phases in extra-terrestrial materials, which can be applied to recent (e.g. OSIRIS-REx) and future (e.g. MSR) sample return missions.

The origin of Main Group pallasites explored using trace element analysis

Ana Pagu[1,2], James F.J. Bryson[1], Claire I.O. Nichols[1], Conall Mac Niocaill[1], Jon Wade[1], Jason Day[3], Andrew Matzen[1]

[1]University of Oxford
[2]Geological Society of London
[3]University of Cambridge

Main Group pallasites are stony-iron meteorites composed predominately of olivine crystals encased in FeNi metal, with minor phosphides and sulfides. Despite their simple mineralogy, the formation of pallasites remains a topic of intense research. Different formation mechanisms have been proposed, including incomplete magmatic differentiation followed by an impact event. This mechanism predicts the Main Group pallasites would contain multiple generations of metal with distinct compositions. To test this hypothesis, we used electron probe micro-analysis and laser ablation inductively coupled plasma mass spectrometry to measure the composition of FeNi metal in regions showing distinct microstructural relationships with the surrounding olivines, in the Seymchan meteorite. We found no systematic compositional difference in the isolated metal trapped between olivine crystals compared to continuous matrix metal, suggesting that all metal shares the same origin. We also measured the IIIAB iron meteorite Henbury, and found compositional similarities to Seymchan, lending further support to the hypothesised genetic link between Main Group pallasites and IIIAB iron meteorites. To reconcile the chemical and textural observations from this study with previous work, we propose a collisional history involving two or more impacts on the pallasite parent body. The first impact injected metal (likely of IIIAB iron composition) into the pallasite mantle, followed by a period of annealing that created texturally equilibrated pockets of metal within olivine aggregates. A second impact led to formation of secondary, unequilibrated features such as fractures and veinlets, without further metal injection. Since pallasite meteorites are thought to originate in different regions of the early Solar System, this formation mechanism is likely to have been common during planetary accretion.

Micrometeorites: New collections, their possibilities and problems

Penny Wozniakiewcz[1], Matthias van Ginneken[1]

[1]University of Kent

Micrometeorites offer a wonderful opportunity to sample the small bodies of our solar system from the comfort of our own home (planet). While studies indicate many are related to larger meteorites, some exhibit quite distinct characteristics, suggesting micrometeorites not merely complement, but expand upon, meteorite collections, providing a more complete picture of the inventory of solar system materials. Collection of micrometeorites is challenging, with these small dust grains vastly outnumbered by terrestrial dust once they arrive at the Earth's surface. Successful collections therefore require either the application of some separation technique, or an approach whereby the amount of background terrestrial dust is limited [1]. Arguably some of the most significant collections have been performed in the Antarctic, however, recent years have seen increased efforts in looking for new ways to collect micrometeorites, with several groups successfully identifying cosmic spherules (melted micrometeorites) in dust collected from rooftops in urban areas [e.g. 2-4]. Recently, we described our efforts to collect micrometeorites directly from the air using ground based vacuum systems [5]. We found small particles consistent with cosmic spherules, including several with the potential to be new sub-types; however, we also identified a plethora of terrestrial spherules created naturally and through anthropogenic means, complicating interpretations. We will describe these various collections, highlight their potential and summarise current efforts to investigate terrestrial sources of cosmic spherule mimics in order to aid interpretations. We also discuss their long term storage as a research resource. References: [1] van Ginneken et al., 2024. Phil. Trans. Roy. Soc. A 382: 20230195. https://doi.org/10.1098/rsta.2023.0195 [2] Genge et al.,2017. Geology 45(2): 119–122. https://doi.org/10.1130/G38352.1 [3] Suttle et al., 2021. MAPS 56: 1531-55. https://doi.org/10.1111/maps/13712 [4] Jonker et al., 2023. MAPS 58; 463-479. https://doi.org/10.1111/maps.13966 [5] Wozniakiewicz et al., Atmospheric collection of extraterrestrial dust at the Earth's surface in the mid-Pacific, accepted, MAPS.

In-situ high-precision isotopic analysis of extra-terrestrial materials at nanoscale

Mahesh Anand[1], Xuchao Zhao

[1]Open University

Major advances in our understanding of the origin and evolution of the Solar System have been made through analyses of samples returned by space missions and meteorites recovered on the Earth. The present decade is witnessing an increase in the cadence of sample return missions, especially with the emerging exploration programmes in China and India. The UK has a rich heritage of world-leading cosmochemistry research, underpinned by cutting-edge analytical infrastructure, spread across multiple institutions and organisations. In this context, the CAMECA NanoSIMS 50L at The Open University is one such world-leading facility serving the UK and the wider cosmochemistry community for over 15 years. The instrument is capable of per mil precision stable isotope ratio measurements for a wide range of elements (from hydrogen to uranium, except noble gases) and element detection down to ppm levels on spots a few microns across as well as high-resolution isotopic and elemental imaging with a spatial resolution down to ~50 nm. NanoSIMS 50L excels in materials science, geology, planetary and space science, microbiology, and cell biology. In the NanoSIMS lab at OU, we have well-developed protocols for geological and extraterrestrial samples. Some of the key research applications are as follows: • High-precision stable isotope analyses (e.g. H, C, O, Cl and S) in samples from the Moon, Mars, and asteroids. • High spatial resolution isotopic/elemental imaging for geological and extraterrestrial samples. We will present highlights from some recent research, using the OU NanoSIMS. The facility is open for collaborative research, exploiting the established analytical protocols. We are also open to developing new and novel methods through pilot projects that could be of interest to the sample science community.

Eucrite Metamorphism in Three Dimensions: A Compositional and Textural Investigation of Pyroxene Clouding with Scanning and Transmission Electron Microscopy

Jennifer T.Mitchell[1], T.J. Barrett[2], M. Odiyzko[1], N. Seaton[1], N.R. Stephen[3,4]

[1]University of Minnesota
[2]University of Manchester
[3]Geological Society of London
[4]Imperial College London

Eucrites are pyroxene-plagioclase basalts and gabbros associated with asteroid 4 Vesta and are the most abundant type of igneous meteorite in the global collection. Pyroxene clouding is a key diagnostic feature used to estimate the degree of thermal metamorpshism experienced by these meteorites on Vesta (900-1000 °C in this case) and is typically identified through optical microscopy but has not been the focus of an in-depth study. Here, we present the preliminary results of a combined compositional and textural study into these clouded pyroxenes through energy and wavelength dispersive spectroscopy (EDS, WDS), electron backscattered diffraction (EBSD), and new analysis from transmission electron microscopy (TEM). Electron microscopical imaging reveals that the clouded pyroxenes are exsolved pigeonite-augite which host oriented and ordered sub-micron to micron scale inclusions. These inclusions are predominantly chromite and are enriched in Ti relative to chromite elsewhere in the samples analysed. EBSD finds no significant deformation in the hosting pyroxene crystal near these inclusions and that the clouding phases are single crystals with single orientations. A TEM lamella of a clouded pyroxene that straddles a pigeonite-augite exsolution lamella shows that the clouding chromite is euhedral in all dimensions and that the orientation of the chromite is constrained by the crystallography of the host pyroxene. EDS analysis of the TEM lamella also finds that the composition of the clouding chromite changes as it crosses from pigeonite to augite, displaying a relative enrichment in Al in the pigeonite side. These results support the view that the clouding phase precipitates from the host pyroxene during high temperature metamorphism and are not the inclusions trapped within the pyroxene during initial crystallisation. Eucrites that host clouded pyroxenes are typically Fe-rich (Fe/(Fe+Mg) >0.4) but not all that fit this compositional requirement display clouding, suggesting that thermal metamorphism on Vesta was often localised.

An update on the UK Planetary Forum

Mark Nottingham[1]

1UK Planetary Forum

The UK Cosmochemistry Analysis Network

Katie Joy[1]

[1]University of Manchester

The UK's National Meteorite Collection

Sara Russell[1]

[1]Natural History Museum

The UK Fireball Alliance: building an all-sky UK meteor observatory

Ashley King[1]

[1]UK Fall

Friday 15th November 2024

Keynote: EnVision Venus: Understanding why our closest neighbour is so different

Phillippa Mason[1]

[1]Imperial College London

Investigating the age and structure of the Ina IMP on the Moon

Lionel Wilson[1], Thomas Jones[1], James W. Head[2]

[1]Lancaster University
[2]Brown University

The irregular mare patch (IMP) called Ina, located at 18.66º N, 5.30 º E on the Moon, is a ~2.9 x 1.9 km wide, ~64 m deep caldera at the summit of a ~25 km diameter shield volcano. The caldera floor contains numerous dome-shaped mounds 5 to 15 m high and 100-500 m wide considered to be formed by extrusions of lava through the cooling crust of a lava lake. The ages of these features deduced from crater counting (~ 33 Ma) are ~100 times younger than the likely ~2 Ga age of recent lunar volcanic activity. A possible explanation for this discrepancy is that the mounds consist of extremely vesicular lava acting like aerogel in which a given meteoroid impact produces a much smaller crater than an equivalent impact into vesicle-free lava. Pilot experiments showed that extremely foamy, unstable lava is readily produced by exposing molten basalt to a modest reduced pressure. Lavas erupted directly into the lunar vacuum must have formed vigorous fire-fountains in which they lost almost all their volatiles and collected in lava ponds around vents, overflowing to form dense, poorly vesicular lavas. However, late-stage lava intruded into a cooling, crusted-over lava lake as at Ina (or intruded into a stagnant, recently-emplaced lava flow) would have exsolved most of any residual volatiles to form a foam as it cooled. The high gas bubble content induced high viscosity and non-Newtonian behaviour controlling the shapes of the mounds on the Ina caldera floor. A NASA CLPS mission to Ina is under development and will carry the DIMPLE experiment to measure both the age and the mechanical properties of the Ina mounds. We are planning experiments to predict the range of material properties that the DIMPLE sampling experiment will encounter, to aid mission planning and hypothesis testing.

Determining the Principal Azimuths of Valles Marineris: A Comparative Analysis of Bezier Spline and GIS Techniques

Dan James[1]

[1]Citizen Science

Valles Marineris (VM), the most prominent example of a Martian Valley Network, has been extensively studied for over 50 years, yet no detailed examination of the principal azimuths of the system exists. To address this, two methods are presented to precisely calculate the principal azimuths, a Bezier Spline analysis, and a GIS technique. The medial axis of the main canyon of VM was determined analytically from cubic polynomial splines fitted to 93 coordinate points along both north and south edges of the canyon. These splines were optimized, and medial axis points were calculated through multidimensional numerical techniques that ensured orthogonality between the tangents of each spline and their connecting normal lines. 1,000 medial axis points were extracted, and various regression models constructed, including fitting to sinusoidal and cubic polynomial curves, achieving accuracies with R2 values of 0.98 and 0.99, respectively. Principal azimuths were obtained using the sinusoidal equation with the slope of the tangent at any point x simply determined by the derivative of the curve's equation. This analytic approach was cross-validated by a GIS method (using QGIS software), where a vector medial axis was obtained which produced principal azimuths that agreed with values from the analytic study with a correlation coefficient of 1.00, and a p value of 6.43e-65. The findings suggest that a deterministic process plays a significant role in the structural geometry of VM, highlighting its potential importance in the canyon's formation.

Applications of digital outcrop modelling techniques to the Interpretation and analysis of small planetary bodies and moons

David Hodgetts[1], Matteo Massironi[2], Brian S. Burnham[1]

[1]VR Geoscience Ltd
[2]Dipartimento di Geoscienze, University of Padova

The exploration of small planetary bodies, including Comet 67P and Mars's moon Phobos, has significantly deepened our understanding of the Solar System's formation and evolution. Central to these studies is the detailed interpretation and analysis of surface features, a task increasingly enhanced by the application of Digital Outcrop Modelling (DOM) techniques. Originally developed for terrestrial geological studies, DOM interpretation approaches have been adapted to the unique challenges of planetary science, offering new ways to interpret surface morphology and unravel the geologic history of these small planetary bodies. A Shape Model is a three-dimensional representation of a celestial body's surface, and are essential for accurately depicting the body's shape, topography, and surface features. They also serve as a foundational element for the application out the DOM interpretation approaches. Shape models, which are often readily available, can be directly imported into outcrop modelling software, streamlining the process of body interpretation. The wide range of surface derived attributes using in outcrop model analysis, such as dip, dip-direction and coplanarity can also be used on shape models to further enhance interpretation, highlighting difficult to resolve features and enabling automated mapping and model segmentation approached. The application of DOM techniques to these bodies also presents unique challenges, particularly in defining the coordinate system for structural measurements. Determining orientations relative to surface features like craters or calculating a local gravity field as a reference surface are critical steps in ensuring accurate structural analysis. By addressing these challenges, researchers can now more easily interpret three-dimensional models of cometary and lunar bodies, enabling more precise measurements and analyses of features such as ridges, craters, and fractures. As the availability and resolution of small body data increases the techniques we apply to outcrop models on earth will become increasingly useful and relevant. In the presentation we will present how some of the outcrop modelling approaches have been used on small body data.

The burial and exhumation of Mount Sharp, as recorded by the fracture sets at Maria Gordon Notch, Gale crater, Mars.

Steven Banham[1], John Cosgrove[1], Gerhard. Parr[2], Maddie Hughes[3], John Grant[4], Claire Mondro[5], Robert Barnes[1], Sanjeev Gupta[1], and Abigail Fraeman[6]

1Imperial College London
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Fractures can record key events during the burial and exhumation of a basin and its stratigraphy. These include: burial, compaction, diagenesis, overpressuring, the fluid origin, and the cause of the stresses. Additionally, fractures can provide a habitable environment, and subsequently, “life” could be preserved in the fracture-fill materials. Between Sols 3319 and 3329, Mars Science Laboratory (MSL) rover Curiosity traversed through Maria Gordon notch – a narrow pass bounded by heavily fractured cliffs – during its ascent of Mount Sharp. The multiple sets of fractures observed here record different stages of the burial and exhumation process. The fractures have been analysed to constrain fracture timing, their cause, and origin of any associated fluids. Initial analysis of the fractures determined that they are tensile (extensional) fractures: the only displacement observed is normal to the fracture plane. No displacement parallel to the fractures has been seen, which is indicative of shear fractures (faults). Most fractures are either approximately vertically or horizontal. None are inclined at either 30 or 60° which is typical of shear fractures. Detailed analysis of the cliffs bounding the pass show four distinct fracture sets which formed in the following order: 1. crossbedding-associated fractures (including bedding, and bounding surfaces); 2. Vertical bedding-bounded fractures (0.01-0.24 m length, mean orientation 192°/82°); 3. Through-going vertical sulphate-fill fractures (max length: 3.3 m, mean orientation ~sub vertical); and 4. open fractures (0.25-4 m length, trend 014-194°). A geological history can be elucidated: 1. Sedimentation, burial and diagenesis; 2. Fracture sets 1 & 2 form in response to compaction and overpressure with increasing lithostatic pressure; 3. Secondary diagenesis cements early fractures and restores rock mass integrity; 4. Fracture set 3 forms, cutting earlier fractures, filled with calcium sulphate from fluids expelled from depth; 5. Exhumation initiated; 6. During unroofing, open fractures form.

Water, water, everywhere: A mineralogical tale of the Bennu asteroid.

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NASA's OSIRIS-REx mission brought 121g of pristine regolith material from asteroid Bennu to Earth in September 2023. The returned sample of Bennu is a very dark coloured, with particle sizes ranging from dust to a stone 3.5cm across. It is highly phyllosilicate rich, with magnetite, carbonate and sulphides all additional major phases. Minor phases include olivine, pyroxene and phosphates (Lauretta, Connolly et al., 2024). The parent of the Bennu asteroid likely formed in the outer Solar System and accreted with ices that melted and reacted with primordial solids to form the mineral array we now observe. The material is highly fragile and would have difficulty surviving entry to the Earth's atmosphere, suggesting that the meteorite collections we have on Earth may be biased towards better consolidated material. Reference: Lauretta, Connolly et al., Asteroid (101955) Bennu in the laboratory: Properties of the sample collected by OSIRIS-REx. Meteoritics and Plan. Sci. https://doi.org/10.1111/maps.14227.

Enceladus: Sampling the Plume

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The STFC Solar System Roadmap 2022 [1] flagged exploring the moons of the outer planets as a priority. Exploring the contents of the sub-surface ocean of the Saturnian moon Enceladus is consistent with both this and the STFC challenge "How widespread is life in the Universe", and was the second highest priority for a new flagship mission in the NASA Decadal Survey 2023-2032 [2]. The Enceladean ocean water can be accessed by flying through the plumes which erupt continually near the south pole. The Cassini spacecraft did this, measuring the salt content in the plume [3] and reporting the presence of low and high mass organic molecules [4,5]. However, Cassini was launched prior to the discovery of the plumes. A future mission would be designed specifically to sample the plumes, revealing more about the contents of Enceladus' ocean and its astrobiological implications. We will discuss the issues related to successful sampling of the Enceladean plumes (type of orbit and fly-by speed), along with sample collection methods (impacts on metals, capture in aerogel, etc.); a recent discussion of this is in [6]. Although such a mission would involve sample collection, it would not involve sample return, so appropriate techniques for in-situ analyses will also be discussed. Such a mission would launch in the 2030s and be active into the 2040s. A separate meeting concerning the exploration of the plumes at Enceladus (and also the volcanic plumes at Io), will take place at the Royal Astronomical Society in London on December 13th, 2024 (see https://ras.ac.uk/events-and-meetings/ras- meetings/blowing-hot-and-cold-exploring-plumes-io-and-enceladus). [1] https://www.ukri.org/wp-content/uploads/2022/12/STFC-050123-RoadmapSolarSystemResearch.pdf [2] https://nap.nationalacademies.org/catalog/26522/origins-worlds-and-life-a-decadal-strategy-for-planetary-science [3] Postberg et al., Nature 459 (7250), 1098-1101, 2009, https://doi:10.1038/nature08046 [4] Khawaja et al., MNRAS 489(4), 5131-5143, 2019, https://doi.org/10.1093/mnras/stz2280 [5] Postberg et al., Nature 558(7711), 564–568, 2018, https://doi.org/10.1038/s41586-018-0246-4 [6] Burchell and Wozniakiewicz, MAPS 59(6), 1358 – 1406, 2024, https://doi.org/10.1111/maps.14152

Half a Glass of Sunshine

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Water is critical for life on Earth and a key resource for human space exploration. As such, how water was delivered to the Early Earth and how do we sustainably extract water from extraterrestrial materials are key science questions. The answer to both may come from an unexpected source: space weathering. Space weathering is the combined processes of irradiation from the sun's solar wind and galactic cosmic grays, and bombardment by micrometeorite impacts. These processes modify the structure and chemistry of every surface exposed to the vacuum of space from satellite components to asteroid surfaces. Here we present recent results using coordinated microscopy including atom probe tomography on grains returned from asteroid Itokawa. Our data reveal a renewable reservoir of water is being continuously produced in the near surfaces of rocky regolith on asteroids and on the Moon by the suns solar wind. Solar wind hydrogen ions being implanted into silicate materials where it reacts to form OH and H2O. Using atom probe tomography, we are able to visualize and quantify this water reservoir. The amount of water produced in fine grained regolith particles is substantial (1 at. %) and could provide a renewable sustainable resource of water on the Moon. In addition, solar wind hydrogen is isotopically light. This provides a isotopically light reservoir of water and means that fine-grained irradiated dust particles could be a key contributor to the early Earth's water budget during late accretion that balance out contributions of heavy water from c-type asteroids.

Hidden in plain sight? On the challenges of detecting molecular markers for life in typical planetary samples.

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Identifying molecular markers for life (as we know it), or lyfe (as we don't know it, Bartlett and Wong, 2020), in planetary samples, is difficult. Original biological signals may be attenuated, complicating analysis. For example, radiolysis of organic matter, host rocks and associated fluids, plus diagenetic processes at shallow burial depths would quickly remove reactive species through cross reaction or mineralization leaving refractory and complex derivative species behind. Both radiolysis and diagenesis also yield complex, higher molecular weight cross reaction products, including sub-elements that could retain biologically specific structure, although these composite structures may not readily appear to have biological character with many existing analytical routes. While molecular complexity approaches such as assembly theory (Sharma et al., 2023) are suggested to provide routes to recognition, these remain controversial (e.g. Hazen et al., 2024) and would be challenged by eligible life molecular structures, hidden in plain view in heterogeneous composite reaction products. For instance, the impressive SAM analysis suite on the Mars Curiosity rover was designed to remotely assess molecular organic matter composition and assess or indicate life markers or alteration products (Eigenbrode et al., 2018; Mahaffey et al., 2012). While Pyrolysis-GC-MS is potentially useful, low carbon contents that promote pyrolysis matrix effects, reactive and oxidative sample matrices, and organic matter alteration due to high surface cosmic ray irradiation levels complicate interpretations. We review our own and published recent studies of the radiolysis of sedimentary organic matter and model compound mixtures (gamma irradiation up to 10 MGy) on durability and detectability of biomarkers and also the preservation of biological component signals in protein-carbohydrate polycondensates as diagenetic models. This work informs planetary sample acquisition and need for new analytical strategies that optimally provide on-site screening and the possibility for improved detection of life markers in complex, altered, sampled, and returned planetary materials.

Planetary seismology: from Mars to the Moon and beyond

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After a lull of nearly fifty years, planetary seismology was reinvigorated by the InSight mission to Mars that from 2018 to 2022 returned the first seismic data since Apollo. InSight's SEIS payload has provided an unprecedented window into the interior of another planet, looking down to the Martian core, revealing the crustal structure and, most recently, offering a new perspective on mantle evolution for a sealed planet. The next opportunity for further seismic exploration will be with the delivered Farside Seismic Suite (FSS), due for launch in 2016 to the southern polar region of the Moon. This payload will provide an opportunity to explore below the lunar surface on the far side of the Moon which missed out on any seismic deployment during Apollo's geophysical investigation. FSS will also provide new data on impact rates and will rely on ground-based citizen-science observations of impact flashes on the nearside of the Moon to pinpoint the source of the seismic waves it detects. Future developments include building up a lunar seismic network as part of astronaut activities. The recent confirmation of current volcanic activity on Venus has also spurred the development of seismic sensors that can survive the harsh environment of that planet's surface. This presentation will review past achievements and future opportunities, with an emphasis on the UK hardware that is contributing, in particular the silicon microseismometers that have operated as part of InSight, are due to launch for FSS and under development for Venus.

Phobos' Origin: A Ground-Truthing Investigation through Laboratory Analysis of Meteorites.

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The origin of Mars' moon Phobos is unknown. Two theories prevail: Phobos is a by-product of a high-energy collision between an asteroid and Mars, which resulted in ejected orbiting material forming Phobos. Alternatively, Phobos is a captured asteroid from the volatile-rich outer Solar System. JAXA's Martian Moons eXploration (MMX) mission is set to visit Phobos and then return samples from the surface to Earth in 2031. The characterisation of these samples will determine the origin of Phobos. To ground-truth MMX's remote observations of Phobos, we have used X-ray diffraction (XRD) and Fourier transform infrared (FTIR) reflectance spectroscopy to characterise the bulk mineralogy and IR spectral properties of carbonaceous chondrites, the composition of which could be indicative of a captured asteroid, and shock darkened ordinary chondrites which could represent a collisional formation. By acquiring XRD and IR data from the same material, mineral abundances can be directly correlated with features in reflectance spectra. We have characterised the mineralogy and spectral properties of six CM (Mighei-like) carbonaceous chondrites, Tarda (C2-ung), the CO (Ornans-like) chondrite Kainsaz, and a range of shock darkened ordinary chondrites. The ordinary chondrites have a brighter overall reflectance than the carbonaceous chondrites in the near infra-red. The CM chondrites and Tarda show a feature at 6 μm from carbonates. The carbonaceous chondrites show spectral features consistent with their phyllosilicate- and carbonate-rich mineralogy, while the ordinary chondrites contain spectral features related to abundant olivine and pyroxene, in good agreement with their XRD patterns. The surface of Phobos exhibits a smooth, red-sloped spectrum with a low reflectance and lack of mafic absorption features, similar to laboratory spectra of Tagish Lake and CM carbonaceous chondrites. We find that the spectral features of Tarda and the CM chondrites show the closest agreement with the spectra of Phobos in the near-IR spectral range.

Nanogeoscience approaches for Mars Sample Return: maximising the outputs of analytical sample science using analogues of Jezero crater sedimentary rocks

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Mars is considered to have been habitable throughout its early history (Noachian–Hesperian), during which period life might have originated and flourished in specific aqueous settings. Since 2021, the NASA Mars 2020 Perseverance rover has explored diverse geological terranes within the Noachian–Hesperian Jezero crater, aiming to characterise palaeoenvironments, detect potential traces of life, and collect a suite of samples of interdisciplinary relevance to planetary scientists. To date, Perseverance has sampled the igneous crater floor, sedimentary rocks throughout the fan–delta sequence, and likely sedimentary rocks at the crater margin. These terranes have variable biosignature preservation potential; fine-grained sedimentary rocks in the delta and crater margin were likely deposited in environments favouring organic biosignature preservation, however, only rare signals consistent with organics have been detected in SHERLOC fluorescence datasets. With the exception of rare spectral features in crater margin sequences, the absence of SHERLOC Raman signals consistent with organics implies a organic concentration below 0.1 wt%. To maximise the science potential of the sedimentary rocks collected, it is necessary to understand how such trace quantities of organic carbon can be detected and characterised in similar geological materials. By virtue of their paucity of organics, broadly equivalent age and dominance by 'primitive' microbial ecosystems, the Archaean geobiological record of Earth provides an exceptional basis upon which to develop analytical strategies to maximise the knowledge creation possible on returned sedimentary samples. Using terrestrial analogues of putatively silica-cemented rocks from the Jezero delta and crater margin (3.3–3.5 Gyr-old cherts from South Africa), and analogues of siliciclastic horizons from the Jezero delta (2.9 Gyr-old sandstones from Australia), I will present and discuss a multi-technique laboratory- and synchrotron-based analytical strategy through which the nanoscale distribution and structural characteristics of organic materials might be elucidated within exceptional horizons of Jezero sedimentary rocks sampled by Perseverance.

Reconstructing the stratigraphic architecture at the apex of a Martian sedimentary fan system at Gnaraloo Bay, Jezero crater, Mars.

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The NASA Perseverance rover is traversing the Jezero western fan, a clastic coarsening upward succession deposited along the western rim of Jezero crater. A transition from distal deltaic deposits to basinward prograding fluvio-deltaic and flood flow deposition is recorded in the upper fan series, bound to the west by the Margin Unit. We present observations from Mastcam-z imaging at Gnaraloo Bay, near the Jezero western fan apex. Gnaraloo Bay was formed by erosion through the upper fan, presenting an opportunity to constrain the relative timing relationships in the upper fan stratigraphy. Shallow crater rimwards and basinwards dipping (<10°) beds from the Margin Unit form the majority of the outcropping area. The Margin Unit underlies an erosional boundary at eastern Gnaraloo Bay, overlain by the inclined beds of the Tenby formation, recording an abrupt transition to a phase of deposition of laterally migrating bedforms. The Tenby formation here is markedly different to its downstream equivalent, lacking the decametre thick, ~25°-30° dipping mouth-bar foresets observed in more distal locations. Sub-horizontal bedding of the Otis Peak member sandstone, formed by deposition in shallow flows, is exposed in hillsides in northern Gnaraloo Bay and the basal contact crosscuts the Margin Unit and Tenby formation. These units are topped by downcutting Boulder Unit deposits. The basal contact of the linear ridge of the Boulder

Unit at Jurabi Point crosscuts the Margin Unit and Tenby Formation, forming an erosional unconformity in which the Otis Peak formation is absent. The boundary geometries indicate that each unit represents a discrete stage of fan development in this location: initial deposition of Tenby migrating barforms over the Margin Unit deposits, followed by deposition of Otis Peak sheetlike sandstones in shallow, lower stage flows which were downcut by the capping boulder deposits formed by late flooding events.

What Depositional Processes and Paleoenvironments Formed the Layered Sulphate Unit in Gale Crater, Mars?

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Since 2012, Curiosity, the Mars Science Laboratory's rover, has been exploring Hesperian-age sedimentary rocks deposited within Gale crater, Mars, to assess whether Mars was once habitable. The rover traversed clay-bearing strata, finding evidence for lacustrine, fluvial, and deltaic depositional environments. Orbital observations revealed a transition from clay-bearing to sulphate-bearing strata, which could indicate an environmental shift into a potential "drier" period. Since 2022, the rover began exploring ~100 metres of this sulphate-bearing strata exposed in a valley known as 'Marker Band Valley' to establish the depositional environments in which these strata formed. The base of Marker Band Valley contains a low-angle cross-stratified unit (>8m thick), sharply overlain by a planar stratified unit (~4.5m thick), containing ~0.7 mm thick, planar, laterally-extensive laminae. A dark-toned, indurated bed (~0.5m thick) overlies this unit, exhibiting symmetrical ripples. This transition is interpreted to represent a shift from lee-face accretion from migrating dunes to an aeolian sand-sheet environment, where dune formation was inhibited by near-surface water, to a shallow lake. Following this, there is predominantly planar stratification expressed as dark-toned and light-toned units (~3-7m thick) exhibiting ~0.7 mm thick laminae with a darker-toned/cemented component and a paler/less-cemented component, a 'pin-stripe' pattern characteristic of wind-ripple migration in a sand-sheet environment. Embedded between two of these units are a set of concave-up scour-and-fill structures (width ~60m; amplitude ~4m) which resemble saucer-shaped aeolian 'blowout' structures. The stratigraphy of the sulphate-bearing unit exposed in Marker Band Valley reveals a dominantly wind-formed sedimentary system interrupted by a transient lake system. The return to an aeolian environment was accompanied by wind deflation producing decametre-scale scours, which may record episodes of enhanced wind activity. Overall, the stratigraphy in Marker Band Valley provides insight into Gale crater's environmental conditions during the Hesperian period and supports near-surface water during the deposition of wind-formed sulphate-bearing strata.

Geochemical and isotopic constraints on the petrogenesis of Plio-Quaternary alkaline rocks from the middle atlas (Morocco): Implications for mantle metasomatism

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Intracontinental volcanic products ranging from nephelinites to subalkaline basalts with Na-alkaline affinity characterize the Plio-Quaternary alkaline volcanic field of the Middle Atlas. Most of these rocks exhibit nearly primitive (undersaturated) silica-rich magmas. The fractional crystallization model has been calculated, indicating that clinopyroxene and olivine are the primary mineral phases involved in fractional crystallization, primarily in alkaline basalts and basanites. Modeling of crustal assimilation and fractional crystallization (EC-AFC) indicates that alkaline basalts have been affected by limited EC-AFC and slightly influenced by crustal contamination, while less evolved rocks are considered to be contaminated. Enrichment in lithophile elements (LILE) and light rare earth elements (LREE; (La/Yb) N = (33.30-13.66)) has been observed from nephelinite to subalkaline basalts, resembling OIB (ocean island basalt) magmas. The evolution of this enrichment is hypothesized to be the result of a difference between decreasing degrees of partial melting and the mineralogy of a garnet-enriched mantle source. Na-alkaline rocks exhibit a relatively limited Sr-Nd-Pb isotopic variation, particularly for uncontaminated rocks ranging from 0.70319 to 0.70357 and from 0.151213 to 0.1512899 in Sr-Nd, respectively. The studied rocks also define a wide range of compositions in Pb isotopic space, significantly enriched, with 206Pb/204Pb ranging from 19.218 to 19.934, 207Pb/204Pb ranging from 15.602 to 15.665, and 208Pb/204Pb ranging from 39.001 to 39.617. This is coherent with the existence of an enriched lithospheric mantle source affected by a likely pre-Cretaceous metasomatic event. The Sr-Nd-Pb isotopic signatures and trace element patterns exhibit an intermediate geochemical signature between depleted mantle (HIMU) and enriched mantle. The presence of a negative K anomaly, enrichment in Ba and Nb, depletion in Rb, and negative peaks observed for Pb maybe reflected by the presence of hydrated minerals like phlogopite and amphibole in the mantle source, which may serve as indicators of metasomatic processes that have affected the source region

POSTER ABSTRACTS

The Fate of Venusian Chlorine

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Despite being Earth's nearest neighbour Venus is the least explored planet in our inner solar system and many aspects of its geologic history remain enigmatic. For example, whilst chlorine has efficiently out-gassed from Earth's interior and is now concentrated in terrestrial surface reservoirs, only trace HCl is present in the atmosphere of Venus. This is surprising as Venus and Earth are alike in size and composition, and the thick, CO2 and N2-rich Venusian atmosphere suggests other volatiles have out-gassed efficiently. In addition, Venus supports no oceans or signs of salt panning, which on Earth act as chlorine sinks. If chlorine was out-gassed from the Venusian mantle as is expected, why is it absent from the present-day atmosphere? Recent work has shown that chlorine is highly soluble in silicate melts, and chlorine may therefore be efficiently sequestered through melt–atmosphere interactions. Existing probe and imaging data reveal low-degree, alkaline volcanics of the type to crystallize chlorine-bearing assemblages (e.g., sodalite) constitute a portion of the Venus' planetary-scale volcanic plains. In this study we explore chlorine sequestration into erupted silicate melts on the Venusian surface which on cooling crystallise chlorine-bearing minerals (e.g. sodalite). Using experimentally determined sodalite-melt partitioning data of chlorine in Venus-relevant systems, our preliminary results show that the sequestration of chlorine into erupted silicate melts would be an efficient mechanism of chlorine in-gassing. The crystallisation of approximately 3.5 wt% sodalite in Venusian surface melts can reasonably account for Venus' 'missing' chlorine budget. Determining the processes involved in shaping Venusian geochemistry through time, particularly as they differ from those operating on Earth, would be a key step towards understanding how and why otherwise identical planets diverge in their geologic evolutions. This work is particularly timely with plans for NASA (VERITAS, DAVINCI) and ESA (EnVision) missions to Venus likely to contextualize our predictions.

Development of a Correlative Workflow in Preparation for the Return of Mars Samples

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To date, the Perseverance rover has collected 25 samples of regolith, rock, dust, and atmosphere from Jezero Crater on Mars as part of NASA's Mars 2020 mission. These samples are due to be returned to Earth in a joint NASA/ESA mission. To prepare for their return, groups of planetary scientists are developing plans for a Sample Receiving Facility (SRF) to host the detailed curation, characterisation and analysis process that will be required to safely receive, analyse and distribute these samples. The SRF pipeline has been split into five main stages (Meyer et al., 2022; Adam et al., 2023) where our focus is primarily on the pre-basic characterisation (tubes sealed) to basic characterisation (tubes opened in pristine containment) stages. Here, we begin developing a correlative workflow for sample analysis from the pre-basic characterisation to basic characterisation stages of the SRF pipeline. Analysis has started using a key Mars Sample Return terrestrial analogue sample from the Isle of Rum, Scotland. This sample – a peridotite thought to be analogous to the olivine cumulate/wehrlite rocks of the Séitah formation, Jezero crater (Thiessen et al., 2024) – has been analysed focusing on the phyllosilicate veins within the olivine grains that appear analogous to those found in Nakhlite Martian meteorites (Hicks et al., 2014) and alteration observed in the Séitah formation. Techniques including X-Ray Computed Tomography (CT), Scanning Electron Microscopy and Focused Ion Beam milling were used to begin characterising the peridotite, with techniques such as Transmission Electron Microscopy to be used in future study. Initial results support the effectiveness of this sample as an analogue for the Séitah formation, displaying poikilitic textures similar to those identified by in situ XRF analysis on Perseverance. We find that these phyllosilicate veins are of serpentine composition and have been resolved in an initial CT scan of the sample.

Icebergs on Early Mars

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Here we present our analysis of HiRISE imaging revealing the presence of scour marks, curvilinear and parallel-sided furrows, and chains of linked and overlapping pits over the larger Martian basins basins, along with meter-sized boulders distributed in clusters and circular mounds, present as isolated features and also in clusters, and covered with small boulders. We show that the association of scour marks with clusters of boulders and mounds can be related to the dual processes of ice keel scouring and ice rafting of both glacial and non-glacial detritus. These processes are well documented on Earth, where they result in distinctive morphologies and sedimentary patterns recognizable on the ocean floor, comparable to those we identified on Mars. The Martian outflow channels may have been subject to erosion and deposition associated with glacial action or ice streaming within ancient ice sheets, including upstream glaciation in the form of moraines, till deposits, eskers, and kame and kettle topography. Icebergs formed at the glaciers termini would have calved seaward of the grounding lines and drifted across the cool northern oceans, carrying with them supraglacial and englacial debris that was deposited on the seafloor as they melted and ablated. Where they ran around, the icebergs created distinctive grooves, chains of craters and mounds on the seafloor all over the Martian lowlands. We conclude that these features can be interpreted as proxy indicators of the former presence of icebergs and sea ice floating in ancient oceans and/or seas on Mars.

Fluvial and Lacustrine Processes on Mars and their relevance to exploring Mars' Habitability.

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Here we investigate a chain of four intersecting craters interpreted to be a series of ancient paleolakes in western Arabia Terra, Mars. We present a reconstruction of the hydrogeological history of these lakes and consider the fluvial and lacustrine history of the region including the implications for Oxia Planum, the future landing site of the ExoMars rover mission. Ancient lake basins provide valuable insights about the environment of Mars. They are important because they are a record of past environments, that could include evidence for early prebiotic processes. The four intersecting palaeolake craters are named Abu, Varahamihira, Aarna and Kyara (the AVAK lake system). Located in western Arabia Terra southeast of the ExoMars Rover landing site in Oxia Planum, the timing and persistence of this lacustrine activity would have been governed by the regional hydrology possibly driven by groundwater fluctuations. Our mapping has identified a variety of tectonic, fluvial and lacustrine processes that occurred in the study region and operated at several phases in time. Examples of key observations include a channel flowing out from Abu crater interpreted to be an outlet that breached the rim when the internal water level reached a spillway point. Also, sediment fans of kilometer-scale spatial extent and with various morphologies are observed within the different craters indicating the direction of water and sediment transport between the lakes as they overspilled their local basins. Crater counting has been used to determine the timing and relative ages of processes the basins experienced. Furthermore, by measuring the geometric properties AVAK's outlet channels we have also been able to constrain estimates of the depth of water in the craters when lakes formed and hence evaluate what AVAK can tell us about the fluvial and lacustrine history of the region.

Carbon in CI Chondrites – Comparing Ivuna to Sample Return Missions

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This study investigates the chemical composition of the CI chondrite Ivuna and the nature of its organic components through Scanning Electron Microscopy (SEM), micro-Fourier Transform InfraRed (FTIR) spectroscopy and Raman spectroscopy to enable comparison to Ryugu and Bennu, the target asteroids of the Hayabusa2 and OSIRIS-Rex sample return missions. Our investigation has shown the effects of terrestrial alteration on Ivuna, forming sulphates through reaction of the phyllosilicate matrix and sulfides with the atmosphere and terrestrial water, seen in both SEM and FTIR analysis, while seeming to leave the overall structure of the organic matter unaffected. Analysis of the Raman data revealed two micrometer-scale regions of thermally evolved organics in Ivuna, showing visibly sharper D and G bands (full width half maximum (FWHM) of down to 115cm-1 and 48cm-1, respectively) compared with the organic matter in the rest of the sample (D band FWHM = 243cm-1, G band FWHM = 88cm-1). However, the trend in the spectral parameters of these heated points also notably does not point towards extracted IOM from Allende, expected to represent homogenised organics heated up to 600 degrees Celsius. FTIR analysis did not observe a corresponding change in the organic components such as an increase in aromaticity as the scale of the heated regions is significantly smaller than that of the FTIR. A possible cause of this micron-scale heating is micrometeorite impacts given the small scale.

The Fluvial History of Noachis Terra

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Recent observations of Mars' surface suggest that ancient sedimentary material crops out across large parts of the planet. Although fluvial valley networks, visible across much of the southern highlands have been recognized since the 1970s, newer data reveals alluvial fans, aqueously altered minerals and aggradational fluvial systems. This evidence suggests that liquid water was present and stable on the Martian surface for prolonged periods (thousands to millions of years) during the Noachian and into the Hesperian period (>3.7-3.5 Ga). Mars palaeoclimate models have struggled to produce environments that match these observations, instead finding that the planet was too cold and icy during its early history for sustained surface water flow. This has led to an "icy highlands" hypothesis in which ice sheets dominated specific parts of the ancient surface, with liquid water occurring only very rarely as ice-melt from these ice sheets. Observations that only some regions of the ancient highlands are dissected by valley networks support this hypothesis. However, more recent observations using high resolution data reveal extensive sinuous sedimentary ridges (interpreted to be inverted fluvial channels or channel belts and referred to as Fluvial Sinuous Ridges, FSRs) in the northern equatorial Arabia Terra region, an area thought to lack fluvial networks. We have extended this search for FSRs to Noachis Terra, a southern highlands region also lacking valley networks, using a global 6 m/pixel image mosaic. We have identified many FSRs, ranging from single segments less than a kilometre long to interconnected, branching networks tens to hundreds of kilometres in length. These FSRs indicate a spatially extensive palaeoenvironment that sustained liquid water flow, building aggradational fluvial systems in large complex networks. The broad and ubiquitous distribution of FSRs suggests a distributed source of water, consistent with a warmer and wetter early Mars and further challenging an icy-highlands scenario.

Advancing Karst Exploration with Remote Sensing and Artificial Intelligence: A Framework for Earth and Planetary Karst Systems

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Remote sensing technologies have revolutionised the study of Earth's surface, including the exploration of karst terrains, particularly in remote or inaccessible areas. This study utilises high-resolution satellite imagery and digital elevation models (DEMs) to identify and map karst landforms, with a special focus on potential subsurface access points. We are exploring various advanced image analysis techniques, including object-based image analysis and decision rule sets, to efficiently detect and classify karst features. To date, we have focused on the Maganik karst, a hard-to-reach limestone plateau in Montenegro, known for its complexity, dramatic vertical relief, and presence of multiple subsurface access points and caves, including Iron Deep, the deepest cave in the country, which reaches depths of over 1,000 metres. While our approaches can be described as semi-automated, the database developed from this study will serve as the foundation for training artificial intelligence (AI) models to autonomously detect karst features across various terrains. This approach has implications not only for Earth-based research but also for planetary exploration, where karst and karst-like processes may occur. As caves and other karst features formed through dissolution are expected in various extraterrestrial environments, including Mars and Titan, we propose a scalable framework for detecting karst features on our planet that could significantly advance our understanding of karstic landscapes beyond Earth.

Meeting convenors:
Natasha Stephen & Thomas Harvey
with support from the Geological Society Conferences Team

Scientific Programme Committee:
Sara Russell (RAS), Mahesh Anand (RAS), Sean Peters (GSA), Helen Brand (GSL), Thomas Harvey (GSL) & Natasha Stephen (GSL)

With thanks to our partners, the Royal Astronomical Society (RAS) and the Geological Society of America (GSA), and support from UK Research & Innovation, Science & Technology Facilities Council (UKRI-STFC).

THANK YOU!

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