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Mars – a new geological frontier

VIRTUAL CONFERENCE

2-4 November 2021

In recent decades, a plethora of orbital and landed robotic missions to Mars have radically altered our understanding of the geological systems, palaeoclimate evolution, and habitability of the planet, and begun a new 'golden age' of Mars research.

This meeting's goal is to discuss the latest findings from all aspects of Mars geoscience. It will bring together specialists working on Mars missions, remote sensing, modelling and meteorites, as well as experts studying analogous systems, techniques, and processes here on Earth. Contributions related to all aspects of martian geoscience are welcomed, as are Mars-relevant studies of Earth or other planetary bodies.

Abstract deadline: 30th September 2021

Convened by:

- Professor Matt Balme - Open University
- Dr Frances Butcher - The University of Sheffield
- Dr Joel Davis - Natural History Museum
- Dr Peter Grindrod - Natural History Museum
- Professor Sanjeev Gupta - Imperial College London
- Dr Lydia Hallis - Glasgow University

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Mars – a new geological frontier

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Day One
Tuesday 2 November

Session 1 - What lies beneath: martian interiors

NASA's InSight Lander: Looking Inside Mars

Anna Horleston

University of Bristol

NASA's InSight lander, the first dedicated geophysics lander to another planet, has been recording a whole suite of seismic and atmospheric data since it's landing in November 2018. The seismic record is almost continuous from early 2019 to the present day. This unprecedented dataset has allowed us not only to catalogue Martian seismicity but also to determine the internal structure of the red planet. The marsquake service has catalogued over 900 marsquakes during the mission, ranging from high frequency events thought to occur within the crust, to low frequency events occurring in the upper mantle. The quakes are different to both Earth and Moon quakes in their duration and dispersion, and we are yet to observe conclusive surface waves, but they have still allowed us to probe the internal structure of Mars.Through the analysis of receiver functions we have determined that the crust under InSight may have two or three layers and is either 20 km or 39 km thick. The average planetary crustal thickness is thought to be up to 72 km. This rules out earlier models suggesting that the average crustal thickness maybe 100 km. From ScS phases we have determined the core radius to be 1830 +/- 40 km – on the upper end of previous estimates implying an iron core enriched with significant quantities of sulphur and other lighter elements. This composition also implies that there is unlikely to be a solid core at the centre of Mars which in turn has implications for Mars' magnetic field. Between the core and the crust, travel time inversions have been used to determine that the Martian thermal lithosphere is between 400 km and 600 km thick. There is also an S-wave low-velocity zone observed in the upper mantle.

Listening for a landing - results from InSight's attempt to detect Perseverance arriving at Mars

Benjamin Fernando

University of Oxford

The Impacts working group of the NASA InSight mission

In February 2021, we used the seismometers onboard the InSight mission to attempt detection of the arrival of the Perseverance Rover at Mars. This was the first time that an experiment of this type had been carried out on another planet, and aimed to provide geological constraints through the detection or non-detection of a source of known magnitude and location.

In this talk, I will present the results from this experiment and touch upon a similar one which took place during the landing of China's Tianwen-1 mission.

Fault system evolution of the Tempe Terra region, Mars

Claire Orlov

University of Leeds

Emma Bramham (University of Leeds), Mark Thomas (University of Leeds), Paul K. Byrne (Washington University in St Louis), Estelle Mortimer (University of Leeds), Sandra Piazolo (University of Leeds)

Tempe Terra is a structurally complex region with a high density of normal faults and graben, located at the north-eastern edge of the Tharsis Rise. This region is of interest because it preserves rocks and structures from the early evolution of Tharsis and lies along the trendline formed by the alignment of the Tharsis Montes volcanoes. Improved high resolution data coverage and recently revised geological unit assignments provide an opportunity to build on previous investigations of the region and review the structural history of Tempe Terra in increased detail. To this end, we completed detailed fault mapping of a 2.3 million km2 study area covering the entire Tempe Terra plateau. More than 23,000 normal faults were mapped and then separated into sets based on their orientation, age, and cross-cutting relationships. This dataset was then used to provide an updated understanding how the fault system at Tempe Terra evolved through time and the relative roles of regional-scale and local-scale tectonic events in shaping the features we observe. Tempe Terra is shown to have 20 different fault sets spanning from the Middle Noachian to the Early Amazonian, at least 4 of which reflect regional-scale events and extensional stress fields of significance to the evolution of Tharsis. Regional and local tectonic activity both peaked in Tempe Terra in the Early Hesperian, which is consistent with the peak of extensional and compressional deformation associated with Tharsis in its most recently revised tectonic history.

Tectonic shortening structures in western Arabia Terra, Mars.

Savana Z. Woodley

The Open University

P. Fawdon (The Open University), M.R. Balme (The Open University), D.A. Rothery (The Open University).

Oxia Planum, the landing site of the ExoMars 2022 Rosalind Franklin rover [1], is located in transitional terrain between the Arabia Terra highlands and the Chryse Planitia lowlands. Here, the Noachian landscape has been exhumed [e.g., 2] and modified by tectonism as part of a regional fabric expressed as 'wrinkle ridges'. The impact of tectonism, on both regional and global scales, on the geological history of western Arabia Terra is poorly understood; it could have implications for palaeohydrology and the elevation of proposed shoreline features [3].

To provide constraints on the tectonic evolution of western Arabia Terra, we have constructed a map of tectonic features using a Context Camera basemap. The widespread tectonic features in western Arabia Terra are thrust-fault-related landforms, termed shortening structures [e.g., 4, 5]. We have classified these features, and recorded scarp height, fault vergence, morphological complexity (i.e., wrinkle ridge, lobate scarp, or high-relief ridge), orientation, stratigraphy, and confidence in a tectonic interpretation.

We have identified numerous shortening structures in western Arabia Terra, with a combined length of ~20,000 km and distributed across all geological units [6]. Analysis of this dataset shows that the shortening structure density (structure length / geological unit area) peaks in Middle Noachian and Early Hesperian aged units. Thus, we suggest that multiple phases of tectonic activity were responsible for the widespread tectonic deformation of western Arabia Terra.

References: [1] Vago et al. (2017) Astrobiology; [2] Quantin-Nataf et al. (2021) Astrobiology; [3] Di Achille and Hynek (2010) Nat. Geosci.; [4] Byrne et al. (2014) Nat. Geosci.; [5] Klimczak et al. (2019) Can. J. Earth Sci.; [6] Tanaka et al. (2014) USGS Map 3292.

Micro Poster Talks 1

NOAH-H: Classifying Oxia Planum using Deep Learning

Alexander Barrett

The Open University

Matt Balme (Open University)

Mark Woods (SCISYS Ltd)

Spyros Karachalios (SCISYS Ltd)

Danillo Petrocelli (SCISYS Ltd)

Elliot Sefton-Nash (ESTEC, European Space Agency)

Luc Joudrier (ESTEC, European Space Agency)

The Novelty or Anomaly Hunter – HiRISE (NOAH-H) is a deep learning [1] terrain classification system [2]. It is designed to perform semantic segregation on High Resolution Imaging Science Experiment (HiRISE) images, classifying the terrain into one of 14 ontological classes. These classes have been tailored to the landscape of Arabia Terra, where the ExoMars Rosalind Franklin Rover will land in 2023 [3].

The aim of the project was to identify aeolian bedforms, blockfields, and rugged or fractured bedrock which might present a hazard to rover operations [4].

A hierarchical classification system was employed. The 14 classes are descriptive, precisely defining variations in surface texture and the arrangement and continuity of aeolian and clastic cover. These descriptive classes were then combined into broader thematic groups, which formed the "interpretive" layer of the system. Thus, an area can be interpreted as being bedrock, non-bedrock, aeolian, or clastic cover based purely on the morphology of the constituent terrains.

The model performed best for discrete features such as aeolian bedforms. Blockfields, and coherent areas of fractured terrain were also identified reliably. It performed least well for transitional forms, and continuous variations from one class to another.

The final run of the model predicted manually classified "expert labels" with a mean Intersection over Union of 74.15% for the full class list and 92.33% for the grouped classes. Misclassified pixels were often found to be distributed randomly through larger areas which had been correctly classified; Coherent patches of incorrectly classified terrain were less common. Therefore, the output is best when examined at the landscape scale, and should be fit for purpose as an input to traversability analysis, and for identifying features of interest at the site.

[1] LeCun 2015, [2] Barrett et al., 2022, [3] Vago et al., 2017, [4] Rothrock et al., 2016.

X-ray Computed Tomography for Basic Characterisation of Mars2020 Samples

Lukas Adam

University of Leicester

John Bridges (University of Leicester)

John Holt (University of Leicester)

Donald Bowden (University of Leicester)

Basic Characterisation (BC) is a set of non-contact measurements to identify the basic physical and geological characteristics of a returned Mars sample in order to inform its later, detailed analysis. It will be performed on all returned Mars2020 samples. Strict contamination control measures must be taken for planetary protection and to prevent contamination of the samples by Earth's environment, so BC will be carried out under high containment. It will include X-ray computed tomography and possibly diffraction; performed on sealed sample tubes as well as later extracted samples. XCT will offer our first view of the collected extraterrestrial material, without having to breach the containment of the sample tubes and start the clock for time-sensitive investigations. These data will be used to inspect tube seal integrity, examine sample shape and state, search for morphological biosignatures, check for signs of contamination, map geological features like grain size and shape, aid in preliminary mineralogical identification, and provide early recognition of high science-priority features.

We are investigating the feasibility and instrument requirements of CT for BC and exploring XRD for BC as well. Four Mars sample analogues have been prepared for this: basaltic fluvio-lacustrine sediment collected for the SAND-E Mars analogue mission from Iceland; and drill-cores of Old Red Sandstone, fluvial mudstone, and basalt. Mars2020 sample tube analogues made out of grade 5 titanium alloy have also been manufactured. CT scans performed on the analogues using Nikon XTH 225 and XTH 320 microtomography scanners have been compared against a proposed set of minimum BC measurement requirements. Samples were scanned inside and outside sample tubes, and minimum requirements met for both cases. We are also measuring the decrease in scan quality caused by beam attenuation due to the sample tube walls and investigating how scan parameters should be adjusted to counteract this.

Ice-Marginal Glacial Meltwater Channels on Earth: Implications for Valley Formation on Mars.

Frances E. G. Butcher

University of Sheffield, UK

Stephen Livingstone (University of Sheffield, UK)

Joel Davis (Natural History Museum, UK)

Zach Dickeson (Natural History Museum, UK)

Anna Grau Galofre (Laboratoire de Planétologie et Géodynamique, France)

We present examples of ice-marginal (including lateral) meltwater channels on Earth, and discuss their importance for testing glacial meltwater hypotheses for the formation of valleys on Mars. Ice-marginal channels form where meltwater produced on glacier/ice sheet surfaces (supraglacial meltwater) flows to the lateral/terminal ice margins. If it encounters reverse topography at the ice margin (e.g. a valley side), it is forced to flow along the margin until it reaches a location where it can flow freely downslope. This forms channels that do not follow the steepest topographic slope. As the ice recedes, it can produce series of parallel ice-marginal channels. Ice-marginal channels form in wet and cold-based glacial systems on Earth, but are most common in cold-based glacial landscapes.

Glacial meltwater has been proposed to explain ancient valleys on Mars' surface, as an alternative hypothesis to precipitation. One suggestion is that cold-based glaciers produced supraglacial meltwater which drained into proglacial valleys extending downslope away from the ice margins. In landscapes with topographic relief similar to Mars' southern highlands, supraglacial runoff from cold-based ice would be expected to form ice-marginal channels in addition to proglacial channels conforming to topographic slopes. The scarcity of ice-marginal channel identifications on Mars poses challenges for hypotheses of 'top-down' melting of cold-based ice for martian valley network formation.

We also urge caution in using deviation from the steepest topographic slope alone to identify subglacial channels formed meltwater flowing beneath wet-based glaciers on Mars. Subglacial meltwater does not necessarily follow the steepest topographic slope due to pressurisation by the overlying ice, but this is not unique to subglacial channels. Ice-marginal channels do not follow the steepest topographic slope, but form subaerially, including in cold-based glacial landscapes.

We highlight the distinctive characteristics of ice-marginal channels on Earth, and compare them to fluvial and subglacial channels, to aid the search for these features on Mars.

Fluvial Sinuous Ridges in the Mawrth Vallis-Oxia Planum Region, Mars: A Compounding of Burial

and Exhumation Processes

Joel Davis

Natural History Museum

Peter Fawdon (Open University)

Livio Tornebene (University of Western Ontario)

The inversion of relief is a common process on both Earth and Mars [1, 2]. Fluvial sinuous ridges (or inverted channels) are widespread across ancient Mars, comprising both inverted landscapes, such as fluvial valleys filled with resistant lava, and exhumed channel deposits, which have become cemented or armoured [2]. Fluvial sinuous ridges comprising exhumed channel deposits are of particular interest because these successions can record long-term palaeo-environmental conditions [3].

We use HiRISE [4] and CaSSIS [5] orbital datasets to investigate a series of fluvial sinuous ridges (FSRs) in the Mawrth Vallis-Oxia Planum region. The FSRs appear to overlie the regionally widespread, Noachian-aged, phyllosilicate-bearing deposits [6]. The FSRs are capped by a dark-toned, resistant material, which in many cases is laterally continuous with impact ejecta, filled valleys, and inverted craters. This suggests that the FSRs here are the result of landscape inversion due to the

presence of the dark-toned, resistant, capping material. However, close inspection of some FSRs reveals that dark cap is mostly surficial and of negligible thickness, and that underlying layered deposits make up most of the ridge structure. Furthermore, some FSRs form multi-storey stacked stratigraphy, interpreted elsewhere as a characteristic of exhumed channel-belts [3]. Taken together, we suggest that the FSRs comprise exhumed channel-belt

deposits, which have been buried by the resistant capping material, and later exhumed. The capping material may represent representing the amalgamation of multiple, indurated impact ejecta materials. Our observations demonstrate that the inversion of relief here may represent a compounding of

multiple processes.

[1] Pain et al. (2007) Icarus, 190(2), 478–491 [2] Williams et al. (2018) ESS, 5, 516–528 [3] Davis et al. (2019) JGR, 124(7), 1913-1934 [4] McEwen et al. (2007) JGR, 112(E5), E05S02 [5] Thomas et al. (2017) SSR, 212(3–4), 1897–1944 [6] Loizeau et al. (2012) PSS, 721(1), 31

Micro Poster Talks 2

Comparison of the Morphology of Alluvial Fan Type Features on Mars to the Qaidam Basin, China.

Maeve McLaughlin

The University of Manchester

Dr Christopher Saville (Durham University)

Alluvial fans occur in craters in the southern highlands of Mars. Understanding the similarity of the morphology of terrestrial analogues to the Martian fans may allow us to infer climatic conditions that influenced the processes by which the alluvial fans formed. Morphological characteristics (fan length, fan width, aspect ratio; concavity, gradient, local relief; catchment and fan area) were quantified for Qaidam Basin and Martian fans. Use of high-resolution orbital images from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) allowed a limited investigation of the mineralogy of Martian fans. It was found that the Qaidam Basin and the Martian fans were significantly similar in some of their morphology. From this, Martian fans were inferred to be formed by fluvial processes. Additionally, both areas indicate that the local relief of the surrounding area is the major control on fan deposition, though Mars is also shown to favour depositing fans on the northern rim of crater walls, possibility indicating snowmelt as a water source. The Martian mineralogy showed that the catchment areas likely formed concomitantly with the fans themselves, and there is some evidence of hydrologically altered minerals on the surface of the fans, though the source is not known.

The quest for signs of chemosynthetic extant life on Mars: advances in theory and evidence

Peter Anto Johnson

University of Alberta, Antarctic Institute of Canada

John Christy Johnson (University of Alberta, Antarctic Institute of Canada)

Austin Mardon (University of Alberta, Antarctic Institute of Canada, Committee on Space Research)

All life consumes energy, which can become converted and result in the production of some form of waste byproduct. Depending on the type of waste product removal system or excretion mechanism utilized by a life form, it may be possible to detect these compounds through indirect means. Currently, there is a lack of evidence for life on the surface of Mars suggesting life may have a specialized subsurface niche characterized by a microbial ecology. Furthermore, there is a possibility for carbon-based anaerobic systems to thrive in such a niche with or without liquid water. In fact, excavation missions have yet to dig underground and as such, there is a possibility an ecosystem for extant life exists beneath Martian surface. Therefore, extant life on Mars may not rely on solar energy but rather chemical energy.

Chemosynthesis is a means for primary energy production on Earth utilized by certain lithotrophic microorganisms that survive in ecosystems reliant on inorganic compounds such as elemental sulfur, sulfur oxide, hydrogen sulfide or iron originating from hydrothermal vents on the ocean floor to meet their energy demands. This provides a basis for scanning similar surfaces on Mars where microorganisms have access to inorganic compounds such as sulfur which can be oxidized to produce energy. Mars' core could be a location of interest based on the requirement for energy. The core of Mars is hypothesized to consist of a mixture of iron, sulfur and perhaps even oxygen. Volcanic surfaces may also be a source of interest particularly with the abundance of gases and compounds such as sulfur and iron for chemolithotrophs.

Chemolithoautotrophs produce redox byproducts, which could be utilized as a biomarker in the search for extant life on Mars. Furthermore, there are regions in the Martian geography abundant with these biomarkers and promising for future exploration

Raman Spectroscopy of Basaltic Mars Analogue Sediments

Donald Bowden

University of Leicester

Prof. John C. Bridges (University of Leicester)

Dr. Candice Bedford (Lunar and Planetary Institute and NASA Johnson Space Center)

Dr. Ian Hutchinson (University of Leicester)

Dr. Melissa McHugh (University of Leicester)

Dr. Hannah Lerman (University of Le

Raman spectroscopy represents a new avenue of geochemical and biosignature investigation for Mars exploration, with two instruments on the Mars 2020 Perseverance rover (SuperCam, a remote sensing instrument with 532 nm excitation and SHERLOC, an in-situ instrument which utilises ~250 nm excitation), and a 532 nm in-situ instrument (RLS) on the ExoMars rover. Analogue studies using terrestrial minerals provide useful comparative data and enable assessment and optimisation of the instruments for specific applications and to determine the limits of Raman spectroscopy in the context of characterising Martian geology.

As part of the NASA-funded Mars analogue mission, SAND-E, unconsolidated basaltic sediments were collected from three sites located at varying distances along a 10 km transect of the Þórisjökull glacio-fluvio-aeolian sedimentary system in SW Iceland. The basaltic sediments in this Icelandic system contain minerals and an amorphous volcanic glass component similar to those detected on Mars, representing a good analogue to the ancient fluvio-lacustrine systems that are expected to have been active at the Jezero crater and Oxia Planum rover landing sites.

We investigate the Raman spectra of these samples, in their unmodified form and as crushed material. In addition, we also test samples doped with carbonate and clay minerals to assess detection limits of these mineral groups. Characterisation was carried out using a Horiba benchtop Raman spectrometer. This equipment incorporates a 532 nm laser, the same as ExoMars RLS, with a similar spot size (~40 μm), laser power at the sample and spectral range (100 cm-1 to 3800 cm-1). Further investigation will be performed using the RLS Simulator, which replicates the specific operation of the RLS instrument even more closely. We present spectroscopic results from these investigations, with comparison of the mineralogy determined through Raman spectroscopy to assessments of the samples obtained through X-ray diffraction, X-ray microtomography and Mössbauer spectroscopy.

Secondary Craters as Absolute Stratigraphic Markers in Oxia Planum, Mars

Peter Grindrod

Natural History Museum

Joel Davis (Natural History Museum), Peter Fawdon (Open University), Emma Harris (Natural History Museum/Imperial College London), Livio Tornabene (University of Western Ontario, Canada)

The ESA/Roscosmos ExoMars Rosalind Franklin rover will land in Oxia Planum, Mars, in June 2023. The main target of the mission are phyllosilicate-rich deposits, estimated to be Noachian (>3.7 Ga) in age [1]. As such, this region likely represents the oldest aqueous environment to be explored in situ. Although relative ages can be determined from orbital data, absolute ages derived from crater size-frequency distribution (CSFD) studies of small (~<100 km2) units are susceptible to errors, due to the limited areal coverage [2]. In this study we aim to use secondary craters within the ExoMars landing ellipse to place confident absolute age markers in the stratigraphic framework of Oxia Planum.

Two main craters are likely to have caused secondary impact craters within the Oxia Planum landing ellipse. A large (~41 km diameter), unnamed crater ~125 km north of the centre of the landing ellipse has ejecta rays made of secondary craters, as well as widespread clusters of secondary craters that extend over 300 km from the crater rim. The ejecta blanket of this crater is not well defined, but is likely ~6500 km2. Kilkhampton crater is a ~16 km diameter crater to the south east of the landing ellipse, with a well-defined ejecta blanket (~1800 km2) that extends into the ellipse itself. Although the distribution of secondary craters is dependent on a number of factors, including impact dynamics, target material, and subsequent surface processes, we will use the morphology of individual secondary craters to determine the primary source crater. These secondary crater events will have an absolute formation age, which can then be placed into the stratigraphic framework of Oxia Planum.

[1] Quantin-Nataf, C. et al. (2021), Astrobiol., 21, 345-366. [2] Warner, N.H. et al. (2015), Icarus, 245, 198-240.

Session 2: Things are still happening! Modern Mars and analogues

Volcanic craters and cones in central Kachchh mainland, western India: potential analogue for the Martian studies?

Anil Chavan

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Subhash Bhandari (Department of Earth and Environmental Science, K.S.K.V. Kachchh University, Bhuj-370001, India)

The Kachchh Basin is a peri-cratonic rift basin in western India, which exposes a vast range of geodiversity representing the past 200 million years of geological history from the Jurassic Period to the recent. The Kachchh basin has preserved several classical terrestrial analogue sites to study planetary science. Kachchh Basin, since the Cenozoic period till date to a larger extent, resembles Noachian - Hesperian transition on Mars. Several potential localities in the basin provide opportunities to explore as the Martian analogues. The magmatism in Kachchh is associated with the northwestern Deccan Continental Flood Basalt Province (CFB) (~65-68 Ma). They form the base of the local Deccan stratigraphy, and their volcanological context is poorly understood. Apart from the flow, there are isolated hills of volcanic rocks, which have stood against the erosional processes that occurred in the basin. This study provides an overview of features indicative of the interaction between water and lava and/or magma in Kachchh and their suitability as analogue for Mars. We have surveyed < 22 craters/cones within the basin for their relevancy as planetary analogue. Evaluated during field investigations and satellite imagery for structures, physiography, and geologic setting concerning climate change from its evolution. The weathering profile and altered aqueous minerals are also proven analogues from the basin. We propose the Dhinodhar, Varar, and other basaltic vents as an analogue for the Ceraunius, Hecates Tholus, and Volcanic Rootless Constructs (VRCs) of Mars.

Keywords: Kachchh Basin; Noachian – Hesperian transition; Planetary analogue; Ceraunius Tholus; Volcanic Rootless Constructs (VRCs)

Modelling the interaction between the atmosphere and surface ice at Lyot crater, Mars

Lori-Ann Foley

The Open University, UK

Matthew Balme (The Open University, UK)

Stephen Lewis (The Open University, UK)

James Holmes (The Open University, UK)

To understand the interaction between the atmosphere and ice deposits found in and around Lyot crater, Mars, we are using a climate model and exploring variations in Mars' orbital parameters, such as obliquity, eccentricity and date of perihelion. Our climate model focuses on small scales (down to kilometres) to study how orbital variations affect the distribution of ice in the atmosphere and on the surface. Lyot crater is a site of particular interest due to its large size, its relatively young age, and that its geomorphology gives rise to a microenvironment that could control the landforms' distribution in and around the crater. It is the site of a number of ice-based features and contains fluvial valley systems that are both the youngest systems of their size and are linked to near-surface ice-rich units. The output from the climate model allows us to make a detailed analysis of the impact of the crater's geomorphology on ice deposition and sublimation, and on the formation of ice-rich landforms over time. We are assessing the effect that high and low points within the crater, and their attendant slopes and shadows, have on the formation of ice-rich features. We compare the modelled output to the observed distribution of landforms to study how climate processes control the long-term evolution of ice reservoirs and present initial results from that study here. When the full set of experiments are complete, we aim to build a timeline for when various units were deposited and altered based on the modelled output.

CaSSIS Colour and Multi-angular Observations of Martian Slope Streaks

Adomas Valantinas

University of Bern

P. Becerra [Uni Bern], A. Pommerol [Uni Bern], L.L. Tornabene [Western Uni], L. Affolter [Uni Bern], G.Cremonese [INAF], E. Hauber [DLR], A.S. McEwen [Uni Arizona], G. Munaretto [INAF], M. Pajola [INAF], A. ParkesBowen [Uni Leicester], M.R. Patel [Open Un

Slope streaks are albedo features that form frequently on equatorial martian slopes. Most slope streaks are dark relative to surrounding terrains, a minor fraction are bright, and rare transitioning streaks exhibit contrast reversal partway downslope. However, their temporal evolution and physical surface properties that are responsible for their brightness variations are not well understood. New observations acquired by the Colour and Stereo Surface Imaging System (CaSSIS) on board ESA's ExoMars Trace Gas Orbiter (TGO) offer insights into the slope streaks' surface microstructure, roughness and particle sizes. By obtaining multiple phase angle observations, we show that dark slope streaks are substantially rougher and more porous than their bright counterparts. Colour data acquired in four wavelength bands suggest a common genetic origin of dark, bright and transitioning slope streaks. The comparison of our orbital results to the laboratory measurements of Martian regolith analogs revealed that particles within dark slope streaks may be up to a factor of four larger than the granular material of surrounding terrains.

Experimental CO2-driven granular flows under Martian atmospheric conditions

Lonneke Roelofs

Utrecht University

Martian gullies are alcove-channel-fan systems which have been hypothesized to be formed by the action of liquid water and brines, the effects of sublimating CO_2 ice or a combination of these processes. Recent activity and new flow deposits in these systems have shifted the leading hypothesis from water-based flows to CO_2-driven flows, as it is hard to reconcile present activity with the low availability of atmospheric water under present Martian conditions. Direct observations of flows driven by metastable CO_2 on the surface of Mars are however nonexistent, and our knowledge on CO_2-driven flows under Martian conditions remains limited. We experimentally tested the limits of CO_2-driven granular flows under Martian conditions with a small-scale flume in the Mars Chamber at the Open University (UK). With our experiments we show that the sublimation of CO_2 can fluidize sediment and sustain granular flows under Martian atmospheric conditions. We also show that the experimental deposits of these gas-driven granular flows resemble the gully deposits on Mars as well as debris- and mud-flow deposits on Earth, but with some key differences. The gas-driven granular flows are sustained under low (<20º) flume angles and small volumes of CO_2 (around 5% of the entire flow). They further show surging behavior, and form multiple lobate deposits with levees and channels. The morphology of the deposits depends highly on the volume of CO_2 to sediment ratio and on the angle of the flume. We therefore can preliminary conclude that CO2-driven granular flows under Martian conditions is a viable explanation for the recent activity and deposits.

Day 2
Wednesday
3 November

Sesssion 3: Little rocks, big secrets:martian meteorites and impacts

The Search For meteorites on Mars

Sara Motaghian

Natural History Museum London & Imperial College London

P. M. Grindrod (NHM London|), R. B Stabbing (NHM. London), E. J Allender (St. Andrews), C. R. Cousins (St Andrews)

Meteorites on the surfaces of other planets has become an increasingly important topic in meteoritics over the last few years. So far over 50 meteorites have been found on the surface of Mars, including 15 officially noted by the meteoritical society. Meteorites can act as a witness plate throughout geological time and provide valuable insight into the history of the site: Chemical and Physical weathering can provide information on climate weathering rates and water-rock interactions; meteorite size and distribution can help infer information about the density of the atmosphere; and chondritic materials could be a potential delivery mechanism for organic materials to Mars. Statistically, Martian rovers have a significantly higher find per mile success rate than dedicated meteorite hunts on Earth and we look to maintain this search capability with the ExoMars Mission. The PanCam instrument, with both the high-resolution camera (HRC) and Multispectral wide-angle cameras (WACs), will be the primary mode of scientific imaging during the ExoMars mission. As such preparations to maximise scientific return and expedite interpretation and analysis of potential meteorite samples is important. Iron, Stony and Stony Iron meteorites show distinct variation across the VNIR spectral range of PanCam captured by the 12-position multispectral instrument. Here we report on our work to prepare the ExoMars PanCam instrument to search for meteorites of the surface of Mars using spectral interpretation tools and spectral parameter mapping, utilising the Natural History Museum London's meteorite collections.

The Carbon Cycle on Ancient Mars: Carbonate Formation and Dissolution

John Bridges

University of Leicester

It is generally assumed that a significant fraction of the ancient thick CO_2 atmosphere on Mars was trapped as carbonate [1]. However, the relative paucity of carbonate detected on the Mars surface has been a puzzling aspect of the predicted carbon cycle on ancient Mars [2]. Our SEM-TEM-XAS studies of the Lafayette nakhlite meteorite [3] have recently shown that initially high abundances of siderite and ankerite carbonate were significantly diminished by hydrolysis, partial breakdown and replacement by ferric saponite, serpentine-like minerals and ferric oxide/hydroxide. During this partial dissolution of the carbonate, it is likely that the phyllosilicate acted as a catalyst for Fischer Tropsch Reactions, acting to reduce carbon oxides to CH_4 and other organics. Recent identification of carbonate in Gale Crater sediments by CheMin XRD [4] is also consistent with major reservoirs of carbon originally trapped as carbonate in the upper martian crust. Siderite carbonates are prone to relatively rapid dissolution and replacement by clays and oxides and so it can be envisaged that the carbonate abundances in a sedimentary terrain, with secondary mineral assemblages reflecting multiple stages of alteration [5], were originally higher. Carbonate dissolution is likely to have been an important part of the ancient carbon cycle on Mars, linking the CO_2-rich atmosphere to the production of some of the CH_4 and organics trapped in the crust.

[1] Bridges J.C. et al. (2019) Carbonates on Mars. In: Volatiles in the Martian Crust, Elsevier. [2] Ehlmann B.L. and Edwards C.S. (2014) Mineralogy of the Martian surface. An. Rev. Earth Planet. Sci. 42, 291-315. [3] Piercy J.D. et al. Carbonate Dissolution and Replacement by Odinite and Saponite in the Lafayette Nakhlite: Part of The CO_2-CH_4 Cycle On Mars? GCA (in rev.). [4] Thorpe M.T. et al. (2021) The Mineralogy and Sedimentary History of The Glen Torridon Region, Gale Crater, Mars. 52nd LPSC, #1519. [5] Rampe E.B. et al. (2020) Mineralogy and Geochemistry of Sedimentary Rocks and Eolian Sediments in Gale Crater, Mars: A Review after Six Earth Years of Exploration with Curiosity. Geochemistry, 80(2).

Providing absolute constraints on the age of martian crust: combined microstructural analysis and in-situ U-Pb chronology of baddeleyite in shergottites

Leanne Staddon

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James Darling (University of Portsmouth)

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Natasha Stephen (University of Plymouth)

Sheila Schuindt (University of Portsmouth)

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Kimberly Tait (Royal Ontario Museum)

Establishing an absolute time scale of martian magmatic processes is critical to understand the evolution and habitability of Mars. In the absence of sample return, radiometric dating of martian meteorites represents the only direct means to achieve this. Within shergottites, the most abundant grouping of martian meteorites in both number and mass, the mineral baddeleyite (monoclinic zirconia; m-ZrO2) is a widespread accessory phase and an important target for in-situ U-Pb chronology. However, most shergottites have undergone significant shock metamorphism (bulk shock pressures ≥28 GPa) during their ejection from the martian surface; while experimental studies indicate robust U-Pb isotope systematics up to ~57 GPa, partial age resetting of baddeleyite has been documented in highly-shocked shergottite Northwest Africa 5298. Pb loss was linked with baddeleyite internal microstructure, formed by recrystallisation and/or reversion from meta-stable, orthorhombic zirconia (≥3.3 GPa; o-ZrO2). To provide additional constraints on the isotopic integrity of shocked zirconia, we have undertaken coupled microstructural and in-situ U-Pb isotopic analyses of baddeleyite in a number of enriched shergottites.

While magmatic microstructures are rarely preserved, we document prevalent transformation to, and subsequent reversion from, o-ZrO2 during shock loading. Degraded crystallinity (diffraction at length-scales ≤50 nm) is widespread, indicative of reversion of o-ZrO2 at post-shock temperatures insufficient to nucleate considerable m-ZrO2. Locally, elevated post-shock temperatures result in micron-scale nucleation of reverted m-ZrO2, though such microstructures are rare in samples without extensive shock melting. Importantly, we observe no link between baddeleyite microstructure and U-Pb isotopic composition. Instead, uncorrected analyses form discordia, indicative of mixing between radiogenic and common Pb reservoirs, and closed system U-Pb isotopic behaviour. Thus, within our studied samples, reversion from o-ZrO2 alone does not induce resolvable U-Pb isotopic disturbance; high and sustained post-shock temperatures are therefore likely required to perturb baddeleyite U-Pb dates. Our approach provides unambiguous magmatic ages, and thus the robust chronological framework required to aid in resolution of outstanding questions regarding martian geological systems.

Counting 90 million craters on Mars to find the source of meteorites

Anthony Lagain

Space Science and Technology Centre, School of Earth and Planetary Science, Curtin University, Perth, Australia

G. K. Benedix (Space Science and Technology Centre, School of Earth and Planetary Science, Curtin University, Perth, Australia; Department of Earth and Planetary Sciences, Western Australian Museum, WA, Australia; Planetary Sciences Institute, Tucson, AZ,

The only Martian rock samples on Earth are ~166 meteorites whose precise origin are currently unknown. Their parental liquid, formed by partial melting of the mantle, migrated through the mantle to the upper crust, where they eventually crystallized. The solidified rocks were then ejected by large meteoritic impacts that initiated their journey to the Earth. Determining the impact locations would provide a context to unravel the Martian interior and its evolution. Here we adapted a Crater Detection Algorithm that compiled a new database of 90 million impact craters, that allows us to determine the potential launch position of Martian meteorites through the observation of secondary crater fields. Using further consideration on the ejection and crystallisation ages of the depleted shergottites (respectively 1.1 Ma old and 330-570 Ma), we found that two craters (30 km and 20 km diameter respectively), both located in the Tharsis volcanic province are the most likely source of this group of meteorites ejected 1.1 Ma ago. This finding implies that a major thermal anomaly deeply rooted in the mantle under Tharsis was active over most of the geological history of the planet, and has sampled a depleted mantle that has retained until recently geochemical signatures of Mars' early history.

Experimental Hypervelocity Impacts into JSC Mars-1:Water-Ice Mixture Targets.

Jack Finch

University of Kent

Penny Wozniakiewicz (University of Kent), Mark Burchell (University of Kent), Luke Alesbrook (University of Kent)

Impact cratering is a geological process common to all of the solid bodies of the Solar System. Comparisons made between the crater morphologies seen on icy satellites to those observed on Mars have been interpreted to suggest the existence of sub-surface water-ice. Studies of impacts into ice-dominated ice-silicate mixtures have determined that the properties of the silicate component are responsible for the observed variations in morphology. Research presented here provides an experimental study of the cratering process in 50:50 ice-silicate mixtures, where the silicate component is either JSC Mars-1 simulant or a standard sand sample. Comparing between the resulting craters will highlight variations in morphology and crater sizes and provide insight into the cratering process applicable to permafrost in the Northern Lowlands on Mars. The ice-silicate mixtures were impacted using the two-stage light-gas gun at the University of Kent. Copper and stainless-steel projectiles were used with velocities between 2km/s to 6km/s. Craters produced in JSC Mars-1 simulant exhibit smaller diameters and volumes but similar depths when compared against those in the ‘sand’ performed under the same conditions. If this trend is applied to the Martian surface, and to larger, planetary scale impacts, then the anticipated Martian crater flux may be shifted towards smaller sizes. Since smaller impact features are more easily removed from a planetary surface, being obliterated by larger impacts, infilling by local activity, this would also have implications for assumptions regarding the impactor population in the inner Solar System and the estimated ages of Martian surfaces.

Session 4: Where once water flowed:Ancient, wet Mars?

Poster Session

First Observations of the Jezero Crater Delta Front by MastCamZ and SuperCam instruments onboard the Perseverance rover

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Mars2020 Science Team

The Perseverance rover landed on 18 February 2021 at the Octavia E. Butler landing site, within Jezero crater. This 45 km diameter crater was selected based on orbital data indicating the presence of alteration minerals (phyllosilicates, carbonates) and of two sedimentary fans. The landing site is located ~2.2 km from the base of the western fan. High-resolution images obtained from the Mastcam-Z camera and from the Remote Micro-Imager of the SuperCam instrument provided ground-based observations with resolutions enabling to capture details smaller than 10 cm from that 2.2 km distance. A 10 m thick unit of inclined strata is observed between two sets of horizontal strata with a sigmoidal geometry at the transition from inclined to horizontal strata. This distinct geometry is interpreted as bottomsets, foresets and topsets typical of deposition in Gilbert-type deltas, thus evidencing deposition into a lake. Elevation of the topset-foreset transition gives the elevation of -2490/-2500 m for the lake level at the time of deposition, thus ca. 100 m below the inlet and outlet valley elevations. Distinct units with boulder-rich deposits are observed at the top of the outcrops. These units are dominated by cobbles and boulders up to 1.5 m large thus highlighting the presence of boulder conglomerates. Such conglomerates are typical of deposition by fluvial floods with high discharge rates enabling to lift up large rocks, typically >100s m3/s. These observations highlight the occurrence of a huge transition in fluvial regime, from sustained flows that built the delta fan to more intense and episodic fluvial floods, which origin may be related to global or regional change in climate such as those expected for more arid or more glacial conditions.

NOAH-H: Deep Learning Terrain Classification of Jezero Crater

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Alexander M. Barrett (The Open University)

Peter Fawdon (The Open University)

Elena A. Favaro (The Open University)

Matthew R. Balme (The Open University)

Mark J. Woods (SCISYS Ltd)

Spyros Karachalios (SCISYS Ltd)

We applied a deep learning [1] terrain classification system, the "Novelty or Anomaly Hunter – HiRISE" (NOAH-H), originally developed for the ExoMars landing sites in Oxia Planum and Mawrth Vallis [2], to the Mars 2020 Perseverance rover landing site in Jezero crater. The NOAH-H model successfully classified the terrain in four HiRISE images of Jezero, according to a suite of 14 ontological classes.. We mosaicked the NOAH-H classified rasters and compared them with a human-made photogeological map of the landing site, and with Perseverance rover and Ingenuity helicopter images. Two raster products were produced, one showing all 14 "descriptive" classes, and the other the five "interpretive" groups set out in [2] We found that grouped NOAH-H classes correspond well with the human-made map and that individual classes are corroborated by the available ground-truth images. The comparison with ground truth can inform decisions as to which ontological classes would be hazardous for rover operations, and which would not. Despite being trained on examples from Arabia Terra, the model transferred well to the unfamiliar test site. In particular, it coped well with variations in orientation of aeolian bedforms compared to those seen in the training dataset. We conclude that our NOAH-H products can be refined to provide one component of more formal traversability analysis of the ExoMars Rosalind Franklin landing site at Oxia Planum. They can also be used to aid the photogeological mapping process.

[1] LeCun, Y.et al. (2015). Deep learning. Nature, 521(7553), 436–444. [2] Barrett, A. M. et al. (2021). NOAH-H, a deep-learning, terrain classification system for Mars: Results for the ExoMars Rover candidate landing sites. Icarus, 114701. [3] Stack, K. M. et al. (2020). Photogeologic map of the perseverance rover field site in Jezero Crater constructed by the Mars 2020 Science Team. Space Science Reviews, 216(8), 1–47.

Hydrological activity duration, sources and climate implications of complex fluvial channel systems

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Common features in many fluvial systems such as the Okavango Valles (OV), Moa Valles (MV) and Karun Valles (KV) systems are multiple, poorly connected channels and thin, complex fans and deltas. These systems are much poorer morphologically expressed and smaller than the mega-outflow valleys and much less complex than the valley networks, but larger and gentler sloped than gully systems. The various flow paths were likely formed by shared flow discharge of water, but in view of their complexity the question is how much time was involved, and whether a single or multiple events formed them. This has implications for the source, the triggers and the links to climatic conditions.

Here we compare OV and MV on both hemispheres on the basis of existing literature, imagery and calculations of flow and sediment transport. The connectedness of the channels and deltas in a single network allow for multiple calculations of the minimum timescale of formation by valley erosion and fan deposition that together constrain the formative timescale much better than in isolated channel-delta systems.

The parallel flow paths often have poorly defined connections suggesting short-lived flow, differential weathering or different lithology between channel segments. OV is about one order of magnitude larger than MV in valley width and volume of valleys and deltas, which are of the order of a cubic kilometer, while MV has more parallel channels.

In both MV and OV, the formative timescale is calculated to be about a year with consistent fluxes and durations for parallel and serial flow paths. However there is a contrast between the southern, upstream part of OV and the northern part: the southern part may have formed in about a month, while the northern part of OV may have required ten years to form. Imagery suggests that the shorter duration event, sourced from the southern system, overprinted a preexisting system in the north, but the source of the latter remains unclear.

The water source in neither system is directly related to climate, so that the intermittency of seasonal precipitation or groundwater fluxes are irrelevant. The southern part of OV, probably of Hesperian age, likely formed from a breached lake that emptied in one event. The MV, probably of Amazonian age, was triggered by a multiple impact on a regional water-bearing substrate and also likely emptied in one wet spell. This history is consistent with reconstructed hydrological activity of many simple and complex channel systems in the literature, including stepped fan systems, branching channels with head scarps, ‘Fresh Shallow Valleys’ and valleys sourced from hot ejecta blankets. Here, presence of ground ice is linked to antecedent global climate and subsurface storage of volatiles, while melting was likely triggered locally throughout the Hesperian and Amazonian.

Update on the mapping of northern Xanthe Terra as a reference site for the Exomars 2022 landing site in Oxia Planum

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University of Münster, Institut für Planetologie, Germany

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ESA's ExoMars rover will land in the Oxia Planum region, which was chosen for its ancient age, evidence for the sustained presence of water, the presence of layered deposits, and the potential for biosignature preservation. It is, however, unclear if the geological setting in Oxia Planum is unique or if it is representative on a regional, i.e. circum-Chryse, or even on a global scale. Additionally, the stratigraphic relationship of the geologic units in Oxia Planum to the nearby ancient impact basin, Chryse Planitia, requires further study. Here, we aim to study the regional stratigraphy and assess the representativeness of Oxia Planum in a circum-Chryse context. To test this, we selected a site in northern Xanthe Terra to investigate key geologic features and compare them to Oxia Planum by mapping the reference site on a 1:100,000 scale. This site displays several characteristics that are similar to those of Oxia Planum: The location at the margin of Chryse Planitia, the presence of layered phyllosilicate-bearing materials, the proximity to fluvial features, and the abundance of remnant mounds and filled ancient craters that are indicative of widespread erosional processes. Fluvial and aqueous features of Xanthe Terra further include several small fluvial (and partly inverted) channels, the Hypanis fan-deposits, and the Shalbatana outflow channel. The geological similarities of both sites enable a comparison and a testing of hypotheses related to the ExoMars rover landing site. Here, we want to give an update on the study progress and the current state of the geological map. Additionally, we aim to contribute to new insights into the fluvial, erosional, and sedimentary history of the circum-Chryse region and the Martian lowland-highland boundary.

Day 3
Thursday 4 November

Session 5: To boldly go: Current and future missions to Mars

CaSSIS – extending mineralogical studies with a low spectral resolution imager

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The CaSSIS team

CaSSIS, on board the ExoMars Trace Gas Orbiter, has several advantages over other high resolution imaging systems that have observed the surface of Mars from low orbit. One key aspect is the spectro-photometric capability of the instrument which results from relatively high signal to noise, stable detector temperature, and its bandpass selection (despite only having four filters). This supports not merely spectacular colour imaging but work is also indicating that correlation with CRISM observations is an effective tool for extending mineralogical mapping and gaining higher spatial resolution knowledge of the distribution of different species locally. Data fusion techniques are also of interest in extending coverage. Such techniques can also provide statistical error analysis – a vitally important control. Given that CaSSIS is still operational, efforts to extrapolate CRISM data using CaSSIS imaging can, of course, be enhanced by new data acquisition. The presentation will highlight images from some, perhaps less well studied, areas on Mars that show mineralogical diversity and will discuss briefly the potential for using CaSSIS to expand mineralogical studies to areas beyond those covered by CRISM data.

It's not over yet: The HRSC Camera on Mars Express after 17 years of observations

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Ernst Hauber (DLR)

Thomas Roatsch (DLR)

HRSC Team

After >17 years of ESA's Mars Express orbiting the Red Planet, the High Resolution Stereo Camera (HRSC) covered >96 % of the surface in stereo and color with scales better than 30 m/pixel. Digital Elevation Models (DEMs) of up to 50 m grid spacing, generated from the stereo coverage, currently cover about 40 % of the surface. In addition to DEMs generated from individual observations, regional-scale multi-orbit DEMs (corresponding to the global USGS quadrangle scheme) are extremely helpful for analyzing spatially extended geomorphological features such as valley networks and their catchment systems. New types of observations are addressing specific science topics such as cloud observations or global colour views of Mars. As Mars Express has a highly elliptical orbit, HRSC has the unique capability to observe the martian satellite, Phobos, at small distances. A global shape model and a near-global orthoimage mosaic could be produced for Phobos. HRSC is also unique because it bridges between laser altimetry and topography data derived from other stereo imaging instruments, and provides geodetic reference data and geological context to a variety of non-stereo datasets. The spectacular 3D views of martian landscapes have attracted the attention not only of the scientific community, but excited the wider public and promoted planetary science in numerous media channels. HRSC has been operated in 6,250 orbits and generated 6 Terabyte of raw data. The instrument is still in excellent health and will continue to produce data until the end of the confirmed mission duration (end-2022) and possibly beyond. We will give an overview on the available HRSC data products and the most significant science results.

Optimising ExoMars PanCam Multispectral Science: Learning Efficient Filter Combinations for the Characterisation of Oxia Planum

Roger Stabbins

Natural History Museum

Peter Grindrod (Natural History Museum), Sara Motaghian (Natural History Museum), Elyse Allender (University of St. Andrews) and Claire Cousins (University of St. Andrews)

The 12 visible–near-infrared narrowband geology filters of the PanCam Wide Angle Cameras, mast-mounted on the ExoMars Rosalind Franklin Rover, will provide preliminary characterisation of the material composition, in particular relating to oxidation and hydration, of the Oxia Planum landing site. A 12-band image cube consumes a significant fraction of the bandwidth limited daily downlink budget of the mission. For this reason there is an incentive to perform critical characterisation activities using a minimal number of bands. Here we use prior knowledge of the mineralogy of Oxia Planum to learn which filters and algebraic filter combinations (spectral parameters) will optimally distinguish the expected material classes. We compute the expected reflectance measured by each filter by sampling candidate minerals from the Western Washington University Spectral Database, and compute all permutations of ratio, slope and band-depth spectral parameters. We rank the filters and spectral parameters by performing Linear Discriminant Analysis on the dataset, finding the filter and spectral parameter linear combinations that maximise the ratio of between-class separation to inter-class separation, with class labels representing the materials to be distinguished. As an example we present results showing the discrimination of hematite against a background of clay and basaltic materials. The toolkit developed for this study presents an efficient and quantitative method for choosing minimal filter images to downlink, for performing routine characterisation of the distribution of minerals indicating the oxidation and hydration of the landing site and rover traverse.

Development and characterisation of a mineralogical simulant for Oxia Planum

Amy Dugdale

The Open University

N. K. Ramkissoon, V. K. Pearson, P. Fawdon, and M. R. Patel (The Open University)

The ExoMars Rosalind Franklin rover will land on Mars in 2023 with the objective of searching for evidence of past or present life whilst also characterising the geochemical environment around the landing site of Oxia Planum [1]. A phyllosilicate-bearing terrain (PBT) has been identified at Oxia Planum using data obtained by the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) and Observatoire pour la Mineralogie, l'Eau, les Glaces et l'Activite (OMEGA) instruments [2,3], the presence of which has been experimentally shown to aid the preservation of organic biosignatures [4]. However, additional minerals not detected from orbit, which may be present at the landing site could also assist in biosignature preservation .

To better represent the mineralogy at Oxia Planum and enable the identification of biosignatures, a simulant is required for experiments on Earth. The simulant is based on minerals identified from CRISM and OMEGA spectral data. These minerals are comparable with PBT at Mawrth Vallis and the in situ detection of phyllosilicates at Yellowknife Bay. XRD data from Yellowknife Bay was used to determine mineral proportions. Based on these observations, the simulant was made from a mixture of plagioclase, orthoclase, pyroxene, Fe-silicate glass, haematite, ferrihydrite, vermiculite, serpentine, olivine and siderite. Owing to sourcing constraints, biotite and serpentine were substituted for chlorite and saponite, respectively.

The simulant will be characterised using analytical instruments analogous to those aboard Rosalind Franklin (Mars Organic Molecule Analyser (MOMA), Ma_MISS, MicroOmega and the Raman Laser Spectrometer (RLS)) as well as lab-based techniques (SEM-EDS, XRF and XRD).

We will present the development and characterisation of this simulant, in addition to experiments it will be used for.

References: [1]Carter et al., (2016) LPSC 47, 2064. [2] Mandon et al., (2020). Astrobiology, 21, 464–480. [3]Vago et al., (2017) Astrobiology, 17, 471–510. [4] dos Santos et al., Icarus, 277, 342–353

Session 6: Clays, water and wind:Getting ready to rove with Rosalind Franklin

The Geological Setting of the ExoMars Rover Landing Site at Oxia Planum

Peter Fawdon

The Open University

ExoMars Rover Science Operations Working group macro group HiRISE mapping team.

The ExoMars rover mission, consisting of 'Rosalind Franklin', the European Space Agency's ExoMars rover, and 'Kazachok', the Roscosmos instrumented lander, will land in Oxia Planum in 2023. Over a nominal mission of 218 martian days (sols) [1], the mission will search for signs of past and present life on Mars and investigate the evidence for physical and chemical biomarkers in the near subsurface.

Oxia Planum is located in transitional terrains [2] on the margin between Chryse Planitia and western Arabia Terra. The landing site is situated in what appears to be a shallow basin [3] dominated by a low relief plains [4] rich in phyllosilicate minerals [5]. These clay-bearing units consist of 'orange' and 'blue' [6] compositional members associated with different scenarios of aqueous alteration [e.g.; 7]. However, the processes by which they formed and the paleoenvironments they represent, early in Oxia Planum's geological history [4], are unknown.

Here we present; (1) a synthesis of work aimed at understanding the geological context of Oxia Planum, (2) ongoing work developing hypotheses about the paleoenvironment of the landing site, (3) the implications of these hypotheses for the identification of biomarkers in the landing site, (4) preliminary work identifying where these hypotheses can be explored and tested within the region of Oxia Planum where the Rover is most likely to land.

[1] Vago et al., (2017), Astrobiology, [2] Tanaka et al. (2014), USGS map #3292, [3] Fawdon et al., (2021), Journal of Maps, [4] Quantin-Nataf et al. (2021), Astrobiology, [5] Carter et al., LPSC 47, #2064. [6] Parkes-Bowen et al., in review, [7] Mandon et al., (2021) Astrobiology

Mapping of the Oxia Planum Clay-Bearing Unit using Colour and Stereo Surface Imaging System (CaSSIS) and HiRISE imagery

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University of Leicester

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Current knowledge of the Clay-Bearing Unit at Oxia Planum, the Rosalind Franklin rover's landing site, is largely based on NIR spectroscopy data from the OMEGA and CRISM instruments. While useful in identifying candidates for the clay mineral present within this unit, and greatly aiding macroscale investigations of the site, the spatial resolution of the data used, at 1200-300m/pixel for OMEGA and 200-100m/pixel for CRISM, limits the data's usefulness for purposes such as high resolution investigation of the landing site or rover traverse planning, even accounting for the small areas where 18m/pixel CRISM hyperspectral data is available.

Images from the CaSSIS instrument, with a pixel-scale of 4.6m/pixel, can improve upon this. The CaSSIS science team have found that certain CaSSIS band ratios reliably differentiate between ferric and ferrous minerals. In a separate study, hyperspectral CRISM, HiRISE colour and CaSSIS data identified two spectrally and morphologically distinct subunits making up the Oxia Clay-Bearing Unit. These are: a lower subunit, appearing orange in CaSSIS/HiRISE colour, which shows extensive metre-scale fracturing and possesses CRISM spectra consistent with containing a Fe/Mg-rich clay; and an upper subunit, blue in CaSSIS/HiRISE colour, showing metre-decametre scale fracturing and CRISM spectra consistent with a mix of Fe/Mg-rich clay and olivine.

Our work demonstrates that ferric detections based on CaSSIS band ratio analyses correlate well with hyperspectral CRISM clay detections, and that the lower subunit has a higher ferric content than the upper subunit. Following this, a higher resolution clay mineral map covering the 1-sigma landing ellipses, differentiating between the two subunits, has been created using CaSSIS band ratios in conjunction with HiRISE greyscale imagery to observe fracture size. The high resolution, coupled with the differentiation of the two clay subunits, means this map provides a significant improvement for detailed investigation of the Clay-Bearing Unit within the 1-sigma landing envelope.

Where There's a Hill, There's a Way: Mounds in the ExoMars Rover Landing Site

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Oxia Planum will be the landing site for the ExoMars 2022 Rover 'Rosalind Franklin' [1]. This low-relief region lies in the transitional terrain between the ancient, rugged highlands of Arabia Terra and the younger, smoother northern lowlands. The landing site contains numerous Noachian-aged geologic features ideal for astrobiological exploration [2]. Amongst the most enigmatic of these features is a population of kilometre-scale isolated mounds, which rise above the otherwise flat clay-bearing plains. These mounds are remnants of a regionally significant Noachian-aged deposit which once dominated the circum-Chryse region [3]. We investigated the geology, morphometrics, and stratigraphic relationships of the mounds in Oxia Planum, and estimated the volumes of the eroded layer in the landing site.

Two sub-units are associated with the mounds: an upper, yellow-toned member comprising most of the topographic mound, and a basal, much thinner, blue-toned member underlying it in CaSSIS images. We observe that the mounds are bounded by unconformities; the unconformity below the mounds represents a Noachian palaeosurface atop the clay-bearing plains, and the unconformity above represents periods of intense erosion. In Oxia Planum, the original mound-forming layer had a thickness of approximately 140 metres – considerably thinner than the ~500 metre thicknesses observed elsewhere around the circum-Chryse margin [3]. This overburden would not have provided enough vertical stress to hydraulically fracture the underlying clays, suggesting a different deformation mechanism is responsible. The minimum erosion rates for the mounds are comparable to previous Noachian erosion estimates [4], and support a warmer, wetter environment than today. Clay-bearing plains adjacent to remnant mounds have had relatively little exposure since deposition of the mound-forming layer – and represent the Rover's best chances of detecting biosignatures in the most recently exposed surfaces.

[1] Vago et al., 2017; [2] Quantin-Nataf et al., 2021; [3] McNeil et al., 2021; [4] Golombek et al., 2006

Periodic Bedrock Ridges in Oxia Planum and the wider Circum-Chryse Region, Mars: preliminary results from a systematic survey

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Periodic Bedrock Ridges (PBRs) are repeating, symmetrical, wind-transverse aeolian abraded linear ridges carved into bedrock. They were first identified in Valles Marineris and Medusae Fosse Formation, Mars [1] and later, on the Puna Plateau, northwestern Argentina [2]. PBRs are abundant at Oxia Planum (OP), the landing site of ESA's Rosalind Franklin rover.

Mapping of PBRs in OP by [3], and subsequent analysis of the distribution against mapped detections of phyllosilicates by OMEGA/CRISM (Observatoire pour la Mineralogie, l'Eau, les Glaces et l'Activite/Compact Reconnaissance Imaging Spectrometer for Mars) from [4], noted the tendency of PBRs to form in layered Noachian clays in OP [5].

This study extended the original OP analysis to an area more than 5 million square kilometers across the Circum-Chryse region. We used the full extent of [4] to bound our study area and conducted an exploratory survey of PBRs in Maja Vallis, Hypanis Valles, Aram Chaos, and Oxia Planum.

Preliminary survey results of the distribution of PBRs (n=3,454) demonstrate the tendency of these ridges to be found in Noachian or Hesperian units6. Overall, 45% of all PBRs are found in clay-bearing units, with 70% of PBRs in OP developing where clay signatures are identified. The orientation of PBR crestlines were consistent across the Cirrcum-Chryse region, with 50% of PBR crestlines oriented ESE/WNW and 95% of all crestlines oriented between E/W and SE/NW. Knowing this, we note the wind direction necessary to form PBRs does not agree with contemporary modelled winds over the region3, suggesting these features formed under a different wind regime.

[1] Montgomery et al. (2012), JGR: Planets, 117(E3). [2] Hugenholtz et al. (2015), Aeolian Res., 18. [3] Favaro et al. (2021), JGR Planets, 126(4). [4] Carter et al., LPSC 47, #2064. [5] Quantin-Nataf et al. (2021), Astrobiology, 21(3). [6] Tanaka et al. (2014), USGS map #3292.

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