UK Mars research and priorit

MEETING REPORT John Bridges and Axel Hagermann summarize an RAS Special Discussion Meeting in January 2011, which looked at the prospects for the UK exploring Mars.

High-resolution imaging and near-infrared mapping of the martian surface, together with detailed studies of martian meteorites and exobiology research, have revealed an increasing amount of detail about how climate and surface processes have changed over the history of Mars. The exploration of Mars is now being planned through a joint NASA–ESA programme. New missions such as the Mars Science Laboratory in 2012 and the Trace Gas Orbiter in 2016 will also improve our understanding about the evolution of Mars. Mission planning is being guided by recent reports of methane in the Mars atmosphere and the identification of minerals and landforms associated with water such as the Eberswalde Delta. Mars research is also acting as a spur for the development of mission concepts and analytical techniques such as new XRD techniques, microRaman and a Life Marker Chip.

The second UK in the Aurora Programme meeting was held on 14 January 2011 at Burlington House, London. The aim was to bring together researchers, particularly in the field of Mars research and instrumentation, in order to provide a platform to show our research and to discuss what the priorities for future missions within Aurora should be. The Aurora programme encapsulates Europe's current plans, aiming to send unmanned spacecraft to explore our neighbouring world to examine its climate, search for evidence of past or present life, and learn how conditions there relate to those on Earth. The meeting was introduced by **Frederick Taylor** (Oxford).

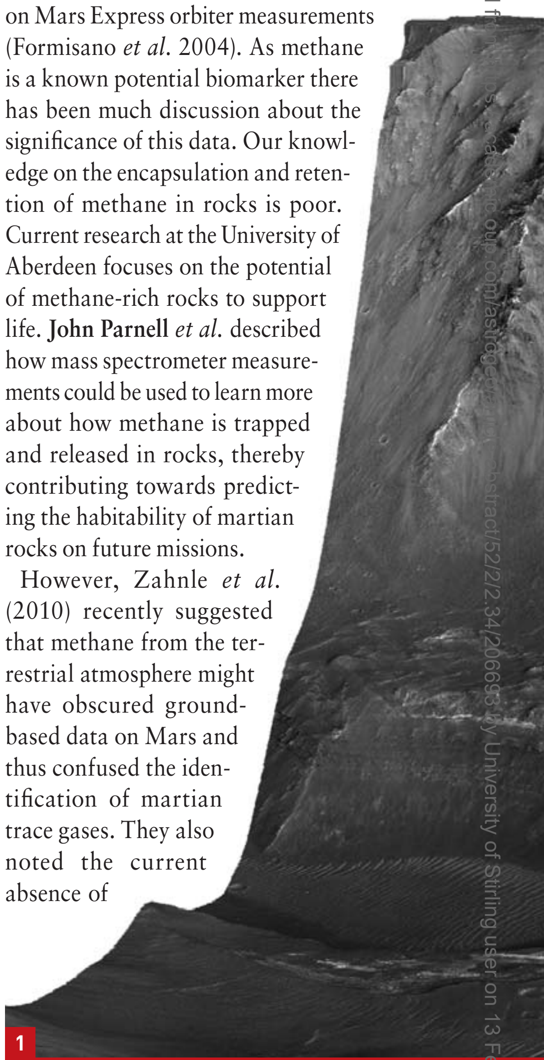
High-resolution imagery of some of the surface of Mars using the HiRise camera on the Mars Reconnaissance Orbiter (MRO) at 25 cm/pixel has changed our view of the evolution of its surface and climate. One of the ways our view of Mars has changed is the recognition of the influence of glacial and periglacial activity in shaping landscapes. **Matt Balme** (Open University) and **Peter Gallagher** (Trinity College Dublin) presented new observations of periglacial landforms that appear to have been formed by water as part of freeze–thaw cycles: self-organized patterns of stone stripes, polygons, circles and clastic solifluction lobes. The low density of impact craters suggests these terrains formed in a geologically recent era. **Kate Goddard** *et al.* (Imperial College) presented a study of youthful gullies and depositional fans on Mars in Mojave Crater. Understanding the role of water or other processes, including CO_2 ice sublimation, in the formation of such gullies is a crucial way of reaching a more accurate understanding of martian climate variations within the last few million years. Balme and Gallagher speculated that because perchlorates (identified at the Phoenix landing site) have eutectic temperatures below 240 K and can remain liquid at temperatures far below the freezing point of water, perchlorate brines may explain freeze–thaw processes and could cause geomorphological changes.

Climate

The ancient climate was studied by **Peter Grindrod** (University College London) using the near-infrared surface-mapping instrument CRISM, which is on board the Mars Reconnaissance Orbiter. This work was able to demonstrate that a set of sediments in part of the Coprates Chasma system of rifts (figure 1) has preserved a record of changing aqueous environment and chemistry. In another example of the use of CRISM, **Kathryn Hill** and **John Bridges** *et al.* (Leicester) showed that other interior layered sediments (ILD) in craters of the Arabia Terra region had an anhydrous mineralogy, consistent in this case with deposition from air rather than water. **Nicholas Warner** *et al.* (Imperial) used new high-resolution imagery and digital terrain models (DTMs) to show that some of the terrains associated with floods such as Ares Vallis (near the 1997 Pathfinder landing site) had undergone multiple floods rather than single, isolated events. Thus current research is showing the complexity and variability of past depositional environments. We are moving on from considering Mars as divided simply into a warm and wet ancient (Noachian) era, pre-3.7 Ga, and a cold and dry Mars after that. Uncertainty in the ages of some of the landforms, including the Eberswalde Delta which is one of the Mars Science Laboratory (MSL) candidate landing sites and considered to have formed through influx of sediment into a standing body of water (**Matt Golombek**, Jet Propulsion Laboratory), is part of this change in our view of the martian past.

One set of presentations at the RAS meeting concentrated on instruments for the 2016 ExoMars Trace Gas Orbiter (TGO). This will have a 400 km, near-circular orbit with solar occultation and near-nadir measurements through the atmosphere; its currently envisaged orbital inclination of 72° will allow coverage of about 95% of the planet. Much of the motivation behind this mission comes from the reports of seasonally and latitudinally variable methane plumes at concentrations between 10 and 60 ppb. These are based on both ground-based infrared observations (Mumma *et al.* 2009) and on Mars Express orbiter measurements (Formisano *et al.* 2004). As methane is a known potential biomarker there has been much discussion about the significance of this data. Our knowledge on the encapsulation and retention of methane in rocks is poor. Current research at the University of Aberdeen focuses on the potential of methane-rich rocks to support life. **John Parnell** *et al.* described how mass spectrometer measurements could be used to learn more about how methane is trapped and released in rocks, thereby contributing towards predicting the habitability of martian rocks on future missions.

However, Zahnle *et al.* (2010) recently suggested that methane from the terrestrial atmosphere might have obscured ground-based data on Mars and thus confused the identification of martian trace gases. They also noted the current absence of



1: Perspective view of light-toned layered deposits at the base of a 3.5 km deep trough in Coprates Catena. The 1 m digital elevation model was made by combining stereo HiRISE images of ~0.25 m/pixel. Image is approximately 7 km wide, with no vertical exaggeration.

2: Sky Crane: proposed landing system for ExoMars and Max-C (and MSL).

3: Martian meteorite alteration: Fe-carbonate, phyllosilicate (smectite and serpentine) with an amorphous gel in the middle.

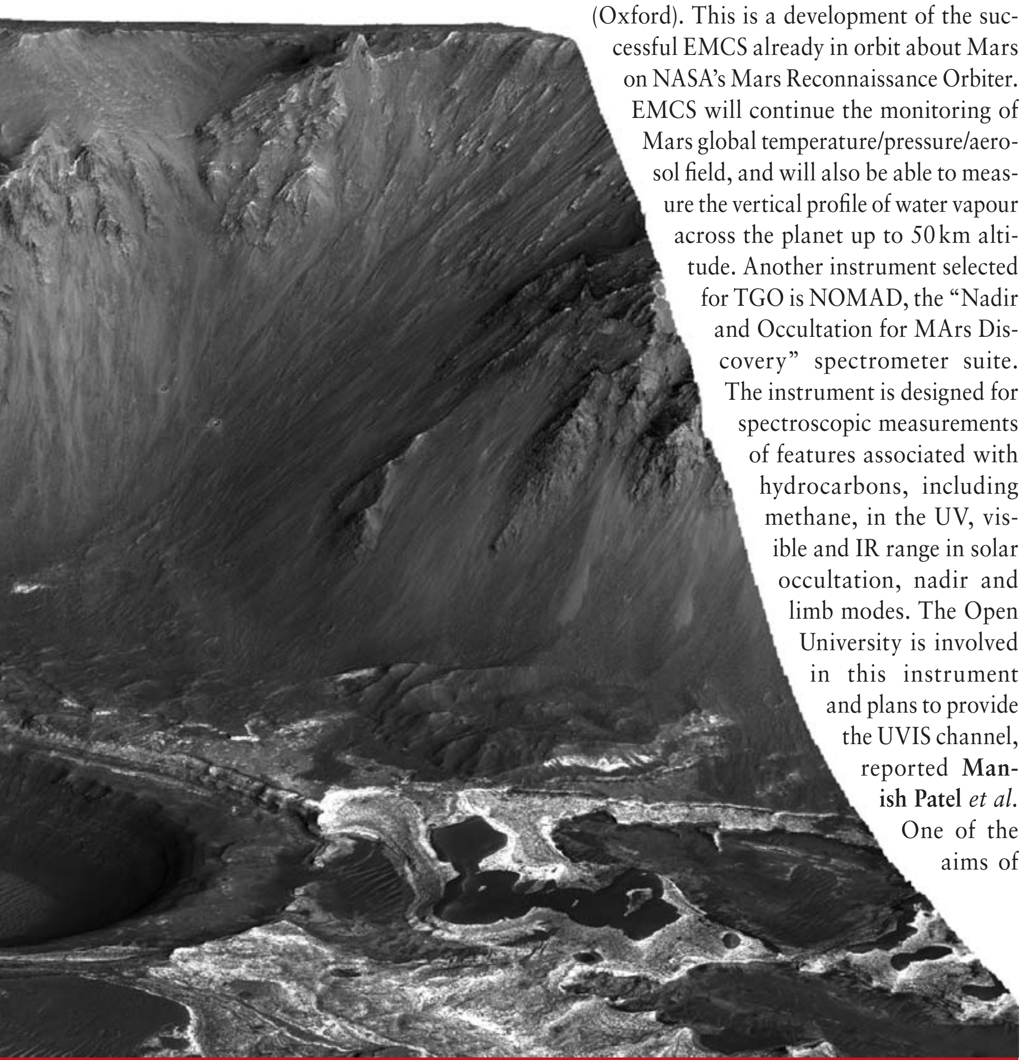
ies in the Aurora programme

a plausible model to explain how methane could be released and trapped on short timescales. Thus the abundance and variability of methane on Mars remains uncertain, and its true nature will not be established without detailed mapping of the atmosphere by TGO at parts-per-trillion levels, together with more accurate global circulation models that include three-dimensional dust transport, water cloud aerosol and chemical species, as discussed by **Stephen Lewis** *et al.* (Open University).

The ExoMars TGO Mars Climate Sounder (EMCS), with key components provided by Oxford, Reading and Cardiff universities, will perform continuous observations of the atmosphere, described by **Patrick Irwin** *et al.* (Oxford). This is a development of the successful EMCS already in orbit about Mars on NASA's Mars Reconnaissance Orbiter. EMCS will continue the monitoring of Mars global temperature/pressure/aerosol field, and will also be able to measure the vertical profile of water vapour across the planet up to 50 km altitude. Another instrument selected for TGO is NOMAD, the "Nadir and Occultation for MArs Discovery" spectrometer suite. The instrument is designed for spectroscopic measurements of features associated with hydrocarbons, including methane, in the UV, visible and IR range in solar occultation, nadir and limb modes. The Open University is involved in this instrument and plans to provide the UVIS channel, reported **Manish Patel** *et al.*

One of the aims of TGO is to monitor active geological processes on Mars. This is a response both to the potential existence of active trace gas seeps and to the recent identification of active geological processes, in particular dune systems, recent impact sites, avalanches, gullies and CO_2 gas jets. The colour capabilities of HiSCI are well suited to this task.

Nick Thomas (University of Bern), who is co-PI of the instrument with the University of Arizona, described how the HiSCI camera (High Resolution Stereo Colour Imager) will enable increased coverage of Mars at 2 m/pixel. There is also a need for increased coverage of Mars with high-resolution DTMs as HiRise will only cover a small fraction of the planet's surface; HiSCI is designed to meet this requirement as well. As well as analysing the geomorphology of the planetary surface, these will allow future landing site planning.



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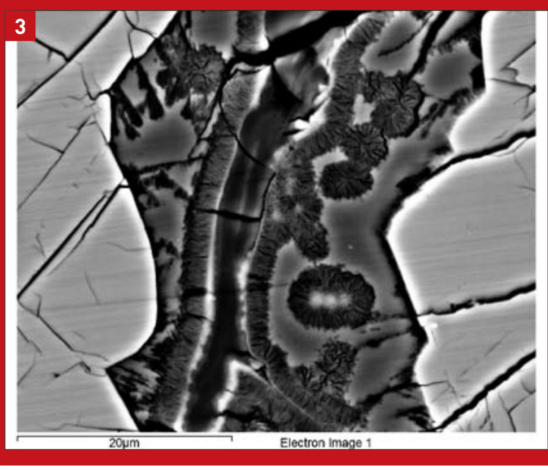

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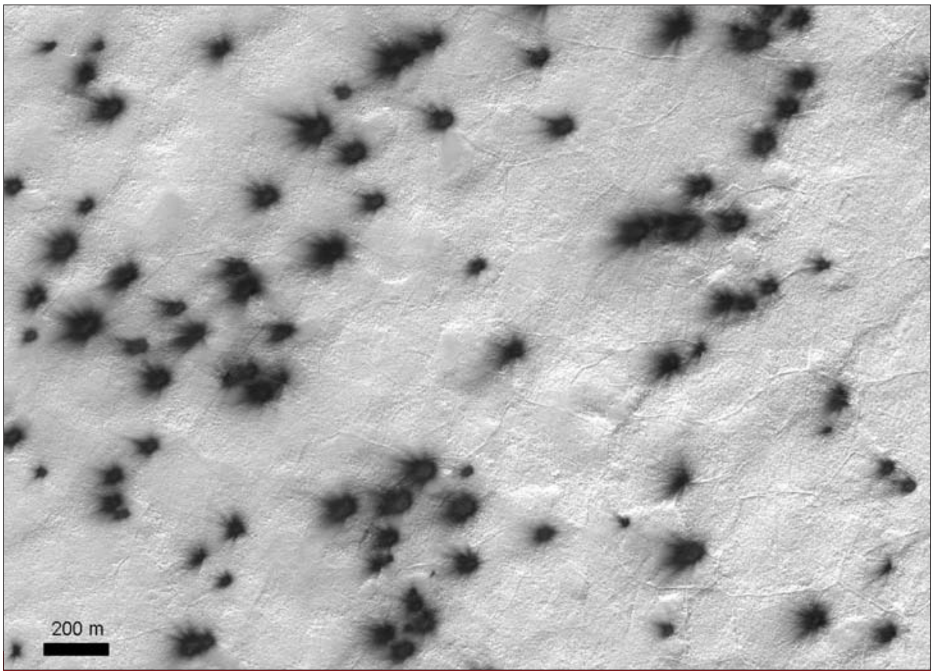
Rovers

The University of Leicester is leading a UK team with MSSL/UCL and the British Geological Survey to collaborate on the HiSCI instrument planning and science exploitation of the upcoming generation of rover missions. Part of this involves developing improved and more automated techniques for the production of DTMs from different datasets and the extraction of data such as surface roughness, described by **Jan-Peter Muller** *et al.* (UCL, MSSL). This will also be of great use in landing site selection and detailed characterization for the ExoMars lander to be launched in 2018. Current mission planning involves landing with Sky Crane technology (figure 2; the same as is being used for the 2012 NASA Mars Science Laboratory rover) together with a NASA-led rover MAX-C. The recent Decadal Review of planetary science has proposed limiting the 2018 landers in order to save $1 billion; thus the exact architecture of the 2018 mission remains to be determined. Golombek (Jet Propulsion Laboratory) described his experience in landing site selection with NASA Mars missions, especially the Mars Science Laboratory with Sky Crane, and outlined the initial engineering constraints possible for the 2018 landing: below 1 km elevation and between 25°N and 5°S latitude. Sky Crane will allow landing accuracy of about a 20 km landing ellipse, compared to 150 km for the current MER rovers. The MAX-C rover will be capable of storing samples for a subsequent Mars Sample Return mission in the 2020s. **Elie Allouis** *et al.* (Astrium Ltd) showed the results of a project to build a "breadboard" prototype



4: This HiRISE image shows the "Starfish" area of the south polar region of Mars. It reveals a large number of fan-shaped deposits which appear to be the result of a geyser-like process involving CO_2 (see Hansen *et al.* 2010 and Thomas *et al.* 2010, 2011).

of a mechanism for moving samples from a drill to a container and then to an ascent vehicle.

The UK planetary science community has long had an interest in sample return missions, such as the Comet Wild2 samples from Stardust currently being analysed at Leicester, Kent, the NHM, Manchester and Open University. The complexity of a Mars Sample Return mission would require international co-operation and a way that the UK might contribute would be to host a sample return facility.

"One lander concept uses a CO_2-rocket-propelled vehicle capable of travelling several kilometres in a 'hop'"

John Vrublevskis *et al.* (SEA Ltd) outlined how COSPAR Planetary Protection Policy places very stringent requirements on sample return missions and "breaking the chain of contact" between Earth and, in this case, Mars. Any contamination or damage to the sample must be avoided until it can be confirmed as not presenting a biohazard and available for subsequent scientific investigation. A sample return facility has never been built before and Vrublevskis outlined an investigation they had made to determine a preliminary design for it.

UK-based institutions are also developing hardware contributions for *in situ* exploration applications such as the ExoMars rover. Part of the current planned payload is a Life Marker Chip (LMC) to detect organic molecules. The LMC is led by the Space Research Centre, University of Leicester, which is also designing detectors for the Raman Laser Spectrometer to identify minerals and organics (**Mark Sims, Ian Hutchinson** *et al.*) and a dual XRD/XRF spectrometer (MarsXRD) (**Kathryn Hill, Graeme Hansford, Richard Ambrosi** *et al.*).

Further research related to instrumentation of the ExoMars rover is being carried out at UCL/Birkbeck (**Claire Cousins** *et al.*), where the filters for the stereo camera system PanCam are being studied. The filter set, virtually unchanged since it was conceived for Mars Pathfinder in 1997, is being redesigned with the astrobiology focus of ExoMars in mind. **Jan-Peter Muller** *et al.* (MSSL, UCL) also showed how PanCam could be used to detect fluorescent spectra and so potentially reveal polycyclic aromatic hydrocarbon signatures. These instruments are being designed so that they are ready to find the relict traces of water. An important way of understanding how interaction with water changed the Mars crust is through the study of martian meteorites. **Leon Hicks, John Bridges** and **Hitesh Changela** (Leicester) showed transmission electron microscopy and XANES analyses from the Diamond synchrotron which revealed the nature of a hydrothermal event that precipitated Fe carbonate, smectite clay and Fe-serpentine (figure 3). The latter could have been associated with the production of methane. The Leicester team argues that the fluid event was initiated by an impact (crater diameter D_c 1–10 km) with rapid cooling. Impacts are one potential habitat for life on Mars. **Charles Cockell** (Open University) demonstrated that volcanic environments were also a likely habitat for microbial life on Mars. He argued that where weathering reactions are extensive, chemolithotrophic reactions which provide energy sources for life could be sustained.

New type of lander

Within the Aurora programme, up to Mars Sample Return in the 2020s, exploration is planned using rovers or, in the case of a seismic network mission, static landers, as discussed by **Agustin Chicarro** (European Space Agency). However, **Hugo Williams** *et al.* (Leicester) argued the need for new lander technologies. They described a Mars Reconnaissance Lander concept which would use a CO_2-rocket-propelled vehicle capable of travelling several kilometres in a ballistic "hop". This makes use of a radioisotope heat source which recharges a heat capacitor after each hop. This type of exploration vehicle would have the advantage of being able to travel hundreds of kilometres, reach higher elevations and traverse rougher terrains than rovers are likely to be capable of.

The Mars mission plans described are now being jointly formulated with NASA and ESA. UK involvement is being managed by the newly established UK Space Agency (UKSA). In a discussion at the end of the meeting about priorities for future missions beyond ExoMars in 2018, **Sue Horne** outlined the UKSA view on the potential Aurora mission following ExoMars.

This mission would be either a Network science mission studying the structure of Mars; Phobos/Demos sample return; precision landing with a rover; or an orbiter which would be an element of the MSR mission capturing the MSR ascent vehicle to return 500 g of samples to Earth. In the current NASA plans the returned sample could be collected by MAX-C. Although not directly in Aurora, collaboration with NASA on an asteroid sample return mission is also possible. Horne suggested that it is unlikely that the UK could afford involvement in both a Mars mission and the ESA mission Lunar Lander in the same timeframe. ●

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Further reading

MEPAG ND-SAG 2008 *Science Priorities for Mars Sample Return* unpublished white paper, 70 pp, posted March 2008 by the Mars Exploration Program Analysis Group (MEPAG) at http://mepag.jpl.nasa.gov/reports/index.html.