**DETECTION AND IDENTIFICATION OF MARS ANALOGUE VOLCANO-ICE INTERACTION ENVIRONMENTS.** C. R. Cousins[1], I.A. Crawford[1], M. Gunn[2], J. K. Harris[1], A. Steele[3] [1]Dept. Earth & Planetary Sciences, Birkbeck College, University of London, UK, WC1E 7HX, [2]Institute for Mathematics and Physics, Aberystwyth University, Aberystwyth, UK, [3]Geophysical Laboratory, Carnegie Inst. Washington DC, USA. Email: c.cousins@ucl.ac.uk.

**Introduction:** Rover and lander missions to Mars form an integral part of planetary exploration, not least due to their ability to conduct in situ analysis and to obtain meter- to sub-meter scale geochemical and visual information. Within the remit of astrobiological exploration of Mars, the identification of palaeoenvironments that were once "habitable", or those that exhibit evidence of past liquid water activity, are of primary interest for missions such as NASA's Mars Science Laboratory and ESA's ExoMars missions.

Cryospheric processes and volcanism have been widespread on Mars throughout its history. On Earth, the interaction between volcanism and ice can be found in present-day Iceland and Antarctica [1]. Such interaction can generate subsurface hydrothermal systems, surface geothermal environments, subglacial volcanic edifices, and explosive phreatomagmatic eruptions. The nature and duration of an eruption, as well as the nature of the local environment sustained in between eruptions, is dependent upon the magma composition, eruption frequency and volume, thickness/volume of ice overlying the volcanic centre, thermal characteristics of the ice, and bedrock topography.

On Mars, numerous examples of volcano – ice interaction terrains and features have been proposed [2], ranging from subglacial volcanic edifices, subglacially-emplaced dykes, out-burst 'Jökulhlaup' style flood terrains, and subsurface hydrothermal systems [2]. As a potentially viable habitat to support life, such interaction can produce a variety of transient environments suitable for a microbial community [1]. As such, the characterisation of the lithological and mineralogical deposits representative of these terrains are investigated, with the aim to improve the detection of similar environments on Mars.

**Analogue fieldsites:** Askja, and Kverkfjöll central volcanoes in north-central Iceland were used to represent both past and present volcano – ice interaction. The terrain around these volcanoes is dominated by subglacial and subaerial eruptions, jokulhlaup deposits, and aeolian processes. Askja is a large caldera, typified by predominantly hyaloclastite deposits and pillow lava outcrops. Kverkfjöll comprises of two subglacial calderas beneath the northern part of the Vatnajökull ice cap, the northernmost of which has several geothermal areas outcropping along the caldera rim. Askja subglacial lavas and volcaniclastics were sampled in July 2007, including pillow lavas sampled from the subglacially-erupted ridges leading from Kverkfjöll up towards Askja. Kverkfjöll was sampled in July 2007 and June 2011. A variety of geothermal soils and hydrothermally altered rocks were collected.


**Fig 1**. Map showing sampling localities (red squares) at Askja and Kverkfjoll volcanoes. Image is 30km across. Orange regions depict geothermal areas around the Kverkfjoll caldera rim (dashed line). *Credit: Google Earth, SPOT 5.*

**Methods:** In-situ and laboratory Vis-NIR reflectance spectra were measured from lava and geothermal samples. Raman spectroscopy and XRD were used to obtain sample mineralogy. Spot 5 satellite imagery (2.5m resolution, multispectral) was used for high-resolution orbital characterization of the sites. Finally, thin section petrology and microprobe analysis was used to analyse sample mineralogy and elemental composition.

**Results:** Samples range from lavas, volcaniclastic sediments, and geothermal soils and altered rocks. This variety is represented in the spectral and geochemical diversity of the samples.

**Fig 2.** Three examples of volcano-ice environment samples (L-R): volcaniclastic hyalotuff, sulfur-rich geothermal deposit, hydrothermally-altered basaltic tuff with iron oxide deposits on the surface. Scale bar = 2cm.

*Mineralogy:* The mineralogy of the pillow lavas varies between all sites (Fig 3). Those at Kverkfjoll are characterised by large plagioclase phenocrysts, whilst pillows between Kverkfjoll and Askja, and at Askja itself, contain secondary mineral deposits including gypsum and jarosite, indicating hydrothermal alteration within the pillow pile, most likely whilst it was still beneath the ice following volcanic activity. All hyaloclastite samples display palagonitisation throughout, but no additional mineral deposits (e.g. zeolites).

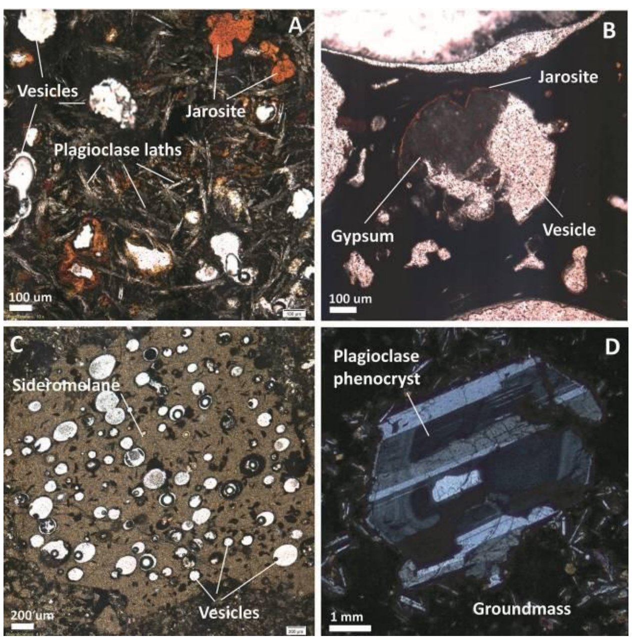


**Fig 3**. Thin section images of (A+B) hydrothermally altered pillow lava, C) hyaloclastite clast, D) plagioclase phenocryst in unaltered pillow lava.

The geothermal samples range from fumarole deposits, unconsolidated geothermal soil, and hydrothermally-altered fine-grained tuffs. XRD analysis groups these, and the lava/volcaniclastic samples into three distinct groups:

1) Diopside + anorthite
2) Alunogen + heulandite
3) Alunogen + heulandite + pyrite + sulphur

In general, samples tend to be dominated by sulphate and sulphide mineral species, and zeolites.

*Reflectance spectra*: As with the bulk mineralogy, samples show three broadly distinct spectral morphologies, although the spectral features do not necessarily match up to the bulk mineral composition. One notable difference is the dominance of $Fe^{3+/2+}$ absorption features in the reflectance spectra, but a lack of Fe-bearing minerals detected by XRD.

Vis-NIR (400 - 1100nm) in-situ spectra were measured from the surface of rock outcrops and soils at the Kverkfjoll geothermal field prior to collection. As with reflectance spectra measured in the lab, spectra are dominated by $Fe^{3+/2+}$ absorptions (Fig 4A and B). These were sub-sampled to the MSL Mastcam, MER Pancam, and ExoMars PanCam 'geology' filter wavelengths [3].

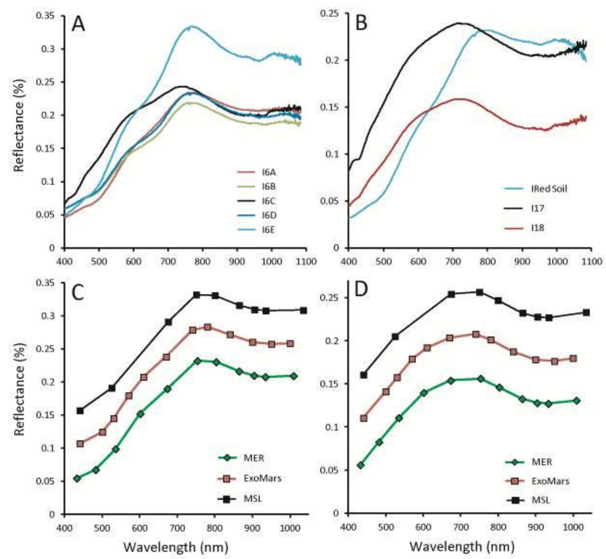


**Fig 4**. A+B) in-situ reflectance spectra of geothermal targets; C+D) the above spectra subsampled to MER, ExoMars, and MSL geology filter wavelengths.

Volcano - ice terrains are represented by morphologically, texturally, and mineralogically diverse outcrops and samples. The identification of hydrothermal activity within these samples will help in the search for past environments on Mars that may have once sustained life.

**References:** [1] Cousins and Crawford (2011) *Astrobiology*,11, 695-710. [2] Head J. W. and Wilson L. (2007) *Annals of Glaciology, 45*, 1-13. [3] Cousins C. R. *et al.* (2010) *Astrobiology*, 10, 933-951.