Martian volcanic systems: using surface strain indicators to investigate magmatically driven stress in the Tharis region, Mars

Dr Emma Bramham (SEE), Dr Mark Thomas (SEE), Dr Paul Byrne (NCSU), Prof Sandra Piazolo (SEE), Prof Douglas Paton (SEE)

Contact email: e.k.bramham@leeds.ac.uk

This exciting project aims to decipher the geological history of Mars utilising the ample spacecraft data collected over the last decade. The novelty of the project lies in using the surface expressions of volcanic systems of Mars to infer the planet's inner workings through time. Scientific outcomes and technique development undertaken as part of the project will be not only important for our understanding of Mars, but also transferable to other planetary bodies – including Earth.

Overview:

Remote sensing of planets and moons across our solar system has provided us with a view of the topography and surface processes of these distant locations. For Mars, the available data is often both of a higher resolution and a far greater spatial extent than those we have for Earth, presenting unprecedented geological insight into the Red Planet. However, although these data allows for measurement and analysis of volcanic and tectonic structures on Mars, our understanding of the sub-surface processes and driving mechanisms for these structures is limited. We therefore look to analogous structures on Earth, of which we have a greater understanding (see Figure 1), but we must also consider differences between both planets, such as lithospheric strength and thickness and variations in surface gravity (Kronberg et al. 2007, Musiol et al., 2016, Heap et al., 2017) that guide the driving mechanisms behind these systems.

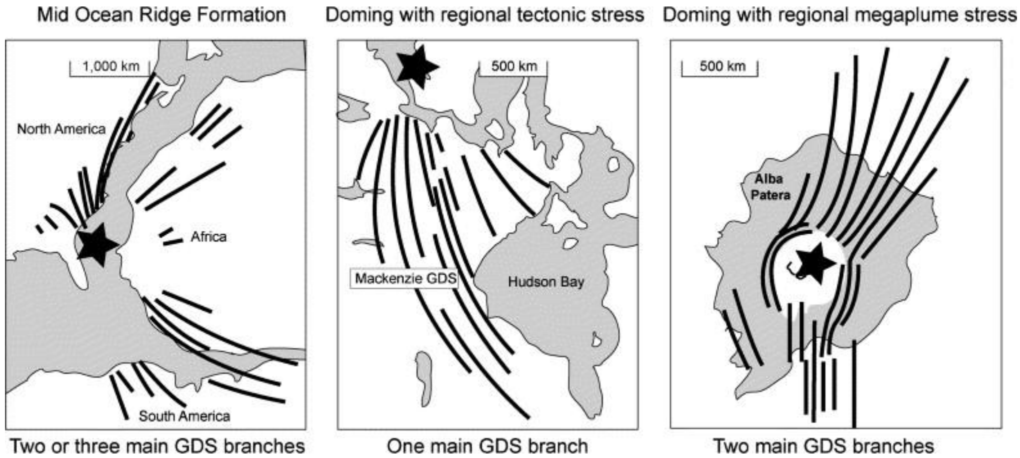

Figure 1: Comparison between the dike swarms of two large hotspot structures on Earth (left and centre) and Alba Mons on Mars (right) (Cailleau et al., 2003).

This study will focus on the ancient volcanic systems in the Tharsis region of Mars and the extensive systems of radial and circumferential grabens there (e.g. Ohman and Mc Govern, 2014). The aim of the study will be to map and quantify surface fault displacement across the region using high resolution remote-sensing data of the Martian surface: MOLA (Mars Orbiter Laser

Altimeter), CTX (Mars Reconnaisance Orbiter Context Camera) and HiRISE (High Resolution Imaging Science Experiment) datasets. The associated strain (e.g. Figure 2) will then be incorporated with appropriate ranges of surface gravity and lithospheric strength to produce potential models of historical volcanic behaviour. The utility of this process will be tested using equivalent Earth-based analogous data over volcanic zones in Iceland.

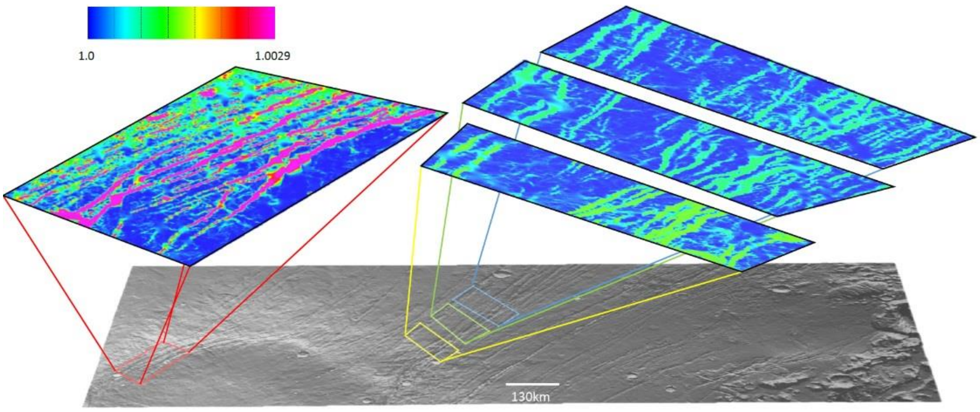

Figure 2: Examples of strain capture analysis (using Midland Valley's MOVE software) in the Alba Mons region, surface strain is extracted from Mars MOLA data (O'Neill, 2017).

Objectives:

In this project, you will work within the Planetary Exploration Group (PEG) here at Leeds and with Dr Paul Byrne at North Carolina State University (NCSU), with access to the support of existing research, data and expertise that both PEG Leeds and the NCSU Planetary Research Group can provide. In particular, according to your particular research interests, the studentship could involve:

1. Analysis of fault systems on Mars, specifically around Alba Mons and other regions of the Tharsis Rise, using MOLA, CTX and HiRISE data to extract, map and compare fault displacement profiles at the different resolutions across the region.
2. Production of associated surface strain maps and use of available Elastic Dislocation (ED) modelling software to produce models of ED and predicted fault plane failure.
3. Development of volcanic modelling processes to include surface fracture prediction via back analysis of measured surface fractures in the Tharsis region.
4. Using a combination of strain measurements from available high-resolution LiDAR data and field work in Iceland to investigate and develop analogous volcanic system models on Earth and to further develop planetary volcanic system modelling processes in general.
5. Utilising Martian meteorite samples to constrain surface material properties and behaviour, including the use of high-end microscopy at UoL as well as possible analysis at synchrotron facilities.

Potential for high-impact outcome

Understanding the volcanic and tectonic history of Mars is a pressing issue, especially in support of planned and future spacecraft missions to the planet. We are in a unique position at Leeds to bring together a range of observational, modelling, and field approaches to answer important unresolved questions about Martian volcanic activity and thermal evolution. The research topic has immediate relevance to improving our understanding of the link between volcanic and tectonic systems. We expect this project to result in several high-impact papers. There will be ample opportunities to deliver the results of the projects at both UK and international conferences.

Training

The student will be given the opportunity to develop a suite of specialist scientific skills in remote sensing, fault analysis and volcanic system modelling. The training will incorporate a wide range of appropriate industry and academic software. Additional theoretical and practical training will be supported through attendance on relevant modules within the MSc Structural Geology with Geophysics, MSc Exploration Geophysics and MSc Engineering Geology programmes.

The student will also be encouraged to become a member of the relevant cross-institute research groups within the school, including Planetary Exploration, Volcanology, Tectonics and Basin Structure. There will be the opportunity, and funding, to present research findings at national and international conferences and workshops. In addition, the student will spend an extended period of time at NCSU under the supervision of Dr Paul Byrne to develop research ideas, collaborate with other staff, and gain experience in analogue modelling techniques with the NC State Planetary Research Group. The student will also have the opportunity to do an element of fieldwork in Iceland and develop field working skills during the project.

The successful PhD student will have access to a broad spectrum of training workshops put on by the Faculty that range from courses in numerical modelling, through to managing your degree, to preparing for your viva (http://www.emeskillstraining.leeds.ac.uk/).

Student profile:

The student should have a strong Geoscience/Physical Sciences background (e.g. Geology, Geophysics, Physics), preferably having undertaken an MSc in Geoscience or related topic, with high competency in quantitative science and spatial modelling.

References

- *Cailleau, B., Walter, T.R., Janle, P., Hauber, E. (2005), Unveiling the original of radial grabens on Alba Patera volcano by finite element modelling, Icarus, v. 176, p 44-56*
- *Heap, M.J., Byrne, P.K., Mikhail, S. (2017), Low surface gravitational acceleration of Mars results in a thick and weak lithosphere: Implications for topography, volcanism, and hydrology. Icarus, 281, p 103-114*
- *Kronberg, P., Hauber, E., Grott, M., Werner, S.C., Schafer, T., Gwinner, K., Giese, B., Masson, P., Neukum, G. (2007), Acheron Fossae, Mars: Tectonic rifting, volcanism, and implications for lithospheric thickness, Journal of Geophysical Research, v. 112*
- *Ohman, T., McGovern, P.J. (2014), Circumferential graben and the structural evolution of Alba Mons, Mars. Icarus, v. 233, p 114-125*
- *O'Neil, J. (2017), Investigating deformation and the effect of planetary gravity in grabens north of the Alba Mons volcano, Tharsis Region, Mars. MSc Thesis, University of Leeds*

- *Musiol, S., Holohan, E.P., Cailleau, B., Platz, T., Dumke, A., Walter, T.R., Williams, D.A., van Gasselt, S. (2016), Lithospheric flexure and gravity spreading of Olympus Mons volcano, Mars. Journal of Geophysical Research: Planets, v. 121, p 255-272*