

**PLANETARY EXPLORATION IN THE TERRESTRIAL DEEP SUBSURFACE: THE MINAR ANALOG PROGRAM.** S.J. Payler<sup>1</sup>, C.R. Cousins<sup>1</sup>, R. Cross<sup>2</sup>, D.C. Cullen<sup>3</sup>, M. Cowling<sup>4</sup>, T. Edwards<sup>5</sup>, A.L. Gray<sup>6</sup>, J. Genis<sup>5</sup>, M. Gunn<sup>2</sup>, G.M. Hansford<sup>7</sup>, P. Harkness<sup>8</sup>, J. Holt<sup>7</sup>, I.B. Hutchinson<sup>2</sup>, J.L. Josset<sup>9</sup>, X. Li<sup>8</sup>, D.S. Lim<sup>10</sup>, D. McLuckie<sup>5</sup>, S.M. Paling<sup>11</sup>, A. Souchon<sup>9</sup>, C.S. Cockell<sup>1</sup>, <sup>1</sup>UK Centre for Astrobiology, School of Physics and Astronomy, Kings Buildings, University of Edinburgh, UK, EH9 3JZ, S.J.Payler@ed.ac.uk, <sup>2</sup>Institute of Mathematics and Physics, Aberystwyth University, UK, <sup>3</sup>The Institute of Aerospace Sciences, Cranfield University, UK, <sup>4</sup>The Crown Estate, UK, <sup>5</sup>Cleveland Potash Ltd, UK, <sup>6</sup>Blekinge Institute of Technology, Karlskrona, Sweden, <sup>7</sup>Space Research Centre, University of Leicester, UK, <sup>8</sup>School of Engineering, University of Glasgow, UK, <sup>9</sup>Space-X institute, Switzerland, <sup>10</sup>NASA Ames Research Centre, California, USA, <sup>11</sup>STFC Boulby Underground Science Facility, Cleveland, UK.

**Introduction:** ‘Analogue’ research involves the use of terrestrial environments that have physical or chemical characteristics similar to extraterrestrial environments to advance science and technology required for planetary exploration. Previous analogue instrument testing has been carried out in a range of environments, from deserts to inland lakes.

One environment that has received little attention for analogue research is the deep subsurface. The subsurface exploration of other planetary bodies offers the potential to unravel their geological history and potential habitability. On Mars in particular, present-day habitable conditions may be restricted to the subsurface. MINAR (Mine Analogue Program) is an analogue program at 1.1 km depth in an active deep subsurface potash mine in the UK, which aims to address this gap in analogue research. The MINAR program’s aims are to:

- i) Test instrumentation designed for planetary exploration in a deep subsurface environment.
- ii) Characterise small and large-scale variations in mineralogy and the relationship these changes have to the presence of biomarkers such as ATP.
- iii) Improve our understanding of sample selection and flow through an instrument cycle when exploring the deep subsurface.
- iv) Develop spin-off technology between the space and mining industries.

**Methodology:** To test instrumentation in the deep subsurface, a multi-instrument suite was used to investigate samples of representative evaporite minerals from a subsurface Permian evaporite sequence at different scales, in addition to *in-situ* halite walls (Fig 1). Instruments used were the Panoramic Camera System (PanCam), Close-Up Imager (CLUPI), Raman, SPLIT, Ultrasonic Drill and handheld XRD. These instruments are proposed for planetary missions or area already scheduled for planetary missions such as ExoMars. These instruments were transported underground and used to characterise samples with a methodical and

thorough working system devised to mimic remote autonomous operations.

**Outcomes:** We show that these instruments can be used to characterise geological context at a variety of scales within a deep subsurface environment. MINAR has allowed for the integrated testing and verification of planetary instrumentation in a deep subsurface context. This work provides the foundation to begin more complex integrated instrument and human exploration testing in the deep subsurface. Ongoing work involves developing spin-off opportunities identified during the program related to mineral characterisation using planetary imaging technology tested in the mine. By carrying out an analogue program in an active mine, spin-off applications can be directly linked to mining.



Figure 1: deep subsurface instrument testing at 1.1km depth examining the variation in halite rock using PanCam (top) SPLIT, a geologist’s hammer (bottom left) and CLUPI (bottom right).

#### References:

- [1] Cockell C. S., Payler S., Paling S. and McLuckie, D. (2013) *A&G*, 54, 2.25-2.27.

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