Combining morphological and organic geochemical evidence for investigating putative ichnofossils: A case study for an approach for the detection of fossilised life on Mars

Graham Purvis\textsuperscript{1}, Cees van der Land\textsuperscript{1}, Naoko Sano\textsuperscript{2}, Peter Cumpson\textsuperscript{3}, and Neil Gray\textsuperscript{1}

\textsuperscript{1}Newcastle University, School of Earth, Ocean & Planetary Sciences, United Kingdom of Great Britain and Northern Ireland
\textsuperscript{2}Ionoptika Ltd. Southampton, UK
\textsuperscript{3}Mark Wainwright Analytical Centre, University of New South Wales, Sydney, Australia

The procedures for detecting fossils on Mars can be derived from the methods that are already used in terrestrial paleobiology (Cady et al., 2003). Here fossils preserving regions are visually located, then inspected for morphological features that might imply fossilised biology (Cady and Noffke, 2009; Westall et al., 2015). Morphological evidence of microfossils on its own is not a completely reliable biosignature (García Ruiz et al., 2002). However, evidence of biological activity may be implanted within the molecular and isotopic composition of organic compounds, which can serve as biosignatures (Summons et al., 2008). Thus, combining both morphological with organo-geochemical evidence could strengthen any argument that a given geological feature could be associated with biological activity. The results from the simultaneous morphological and geochemical analysis of geobiological structures on Earth could provide evidence that any comparable structures that may be observed on Mars, are potentially connected to biological activity, and therefore, may be suitable for collection for return to the Earth, for further analysis.

As a proof of concept, the distribution of the organic material that is associated with distinctive microtubules in the glassy volcaniclastic shards within tuff, that have been suggested to be putative ichnofossils (Banergee and Muehlenbachs, 2003), these were analysed by us using X-ray photoelectron spectroscopy, nanoSIMS and the Ionoptika J105 time of flight secondary ion mass spectrometer, with an argon gas cluster ion ion beam. This indicated that nitrogenous organic material occurred in regions of the sample that were rich in microtubule textures and in the surrounding microfractures (Sano et al., 2016).

These results demonstrated that the J105 ToF-SIMS combined with XPS and GC/MS analysis is able to match geomorphological features with their organic and inorganic composition at the \textmu m scale, which may be a useful approach for the identification of fossilised life on Mars.

**References:**
