TRACE ELEMENTS ASSOCIATED WITH MICROFOSSILS IN TERRESTRIAL HOT SPRING ENVIRONMENTS: A NEW BIOSIGNATURE TO AID IN THE SEARCH FOR LIFE ON MARS. Andrew Gangidine[1], Malcolm R. Walter[2], Jeff R. Havig[3], Andrew D. Czaja[4], and Evan E. Groopman[5], [1]NRC postdoctoral fellow at the US Naval Research Laboratory, andrew.gangidine.ctr@nrl.navy.mil, [2]School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney, Australia, profmalcolmwalter@gmail.com, [3]Department of Plant and Microbial Biology, University of Minnesota, Minneapolis, MN, jhavig@umn.edu, [4]Department of Geology, University of Cincinnati, Cincinnati, OH, andrew.czaja@uc.edu, [5]Materials Science & Technology Division, US Naval Research Laboratory, Washington, D.C., evan.groopman@nrl.navy.mil.

Introduction: On Earth, demonstrating the biological origin of ancient fossils is often difficult due to poor preservation and alteration. This problem will be exacerbated for missions searching for evidence of past life outside of Earth, such as NASA's Mars 2020 mission, since it is still not known if life arose elsewhere. Finding microbial fossils (microfossils) would provide the most direct evidence of life, but even on Earth the biogenicity of ancient microfossils is often debated owing to simple morphology and highly altered host rocks. Thus, as morphology alone is often not sufficient for demonstrating the biogenicity of microfossils and other microbial structures, other geochemical biosignatures are required and are most effective when multiple lines of evidence are applied and are each consistent with a biological interpretation. Since surface and sample-return-based missions seeking evidence of past life are currently underway on Mars, it is crucial to perform research at Mars-analog environments on Earth to help inform arguments for or against any potential biological interpretations. We report here our results from terrestrial analog studies highlighting a biosignature detection method based on trace element abundances relative to silicified microbial life in unaltered and altered terrestrial hot spring deposits.

Background and Results: Terrestrial hot springs are known for their high preservation potential for microbial remains, largely due to rapid silica deposition that entombs microorganisms [1]. Such spring deposits are thought to exist on the surface of Mars, and are sites of prime astrobiological interest [2]. In previous work, we developed a method to map trace elemental concentrations of microfossil-bearing amorphous (unaltered) silica deposits in Yellowstone National Park using secondary ion mass spectrometry (SIMS). These results indicated that certain trace elements are preferentially enriched in hot spring dwelling microorganisms, and are subsequently preserved over ~10 Ka [3]. To test the robustness of this biosignature, we analyzed microfossil-bearing quartz (highly altered silica) samples from an extinct mid-Paleozoic terrestrial hot spring deposit in Drummond Basin, Australia [4]. Enrichments of Mg, Al, Mn, Fe, and Sr were found to be consistently co-localized with primary C and S signals in microfossil bodies (Fig. 1) [5]. These elemental signatures seem to persist over hundreds of millions of years and through substantial diagenetic alteration, and may be useful in the search for ancient life on Mars.

Future Analyses: Despite the promising application of SIMS for this work, this analytical technique is challenging for samples with complex matrix compositions and extremely low trace elemental concentrations. To surmount these issues, we will employ the Naval Ultra-Trace Isotope Laboratory's University Spectrometer (NAUTILUS), a combination SIMS and accelerator mass spectrometer located at the US Naval Research Laboratory [6]. The NAUTILUS mitigates issues common to SIMS analyses (most notably molecular isobaric interferences), and achieves an instrumental background level of <1 count/hour, far below the detection limits achieved by conventional SIMS. Because of these benefits, the NAUTILUS' sensitivity to trace elements is at least 10× better than commercial SIMS instruments. By utilizing the NAUTILUS, this biosignature can be further developed for eventual application to samples returned to Earth from Mars.

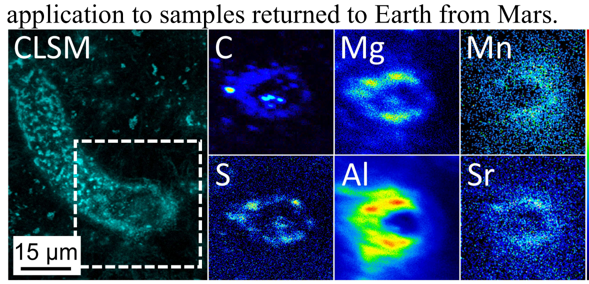

Figure 1. SIMS mapping of ancient life. Left: Confocal laser scanning microscopy (CLSM) scan of a Drummond microfossil. The white box indicates the area targeted for SIMS analyses, with subsequent panels (right) showing the SIMS-generated maps for noted elements. Color bar shows relative intensity from low (black) to high (red). Scale bar applies to all panels.

References: **[1]** Cady S. L. and Farmer J. D. (1996) *Proceedings of the Ciba Foundation Symposium,* 150–173. **[2]** Ruff S. W. et al. (2019) *Astrobiology, 20(4),* 475–499. **[3]** Gangidine A. et al. (2020) *Astrobiology, 20(4),* 525–535. **[4]** Walter M. R. et al. (1996) *Palaios, 11(6),* 497-518. **[5]** Gangidine A. et al. (2021) *Life, 11(2),* 142. **[6]** Groopman E. E. et al. (2020) *Journal of Analytical Atomic Spectrometry, 35(3),* 600-625