ASTROBIOLOGICAL ASSESSMENTS OF GEOBIOLOGICAL FEATURES WITHIN HABITABLE ENVIRONMENTS: DEVELOPING THE GEOBIOLOGICAL HANDBOOK OF MEASUREMENTS FOR LIFE DETECTION. P. Cortez[1] and S. M. Perl[1-3],[1]NASA Jet Propulsion Laboratory, California Institute of Technology, JPL Origins and Habitability Lab, 4800 Oak Grove Drive, Pasadena, CA 91109, [2]Mineral Sciences, Los Angeles Natural History Museum, Los Angeles, CA 90007, [3]Blue Marble Space Institute of Science, 600 1st Avenue, Seattle, Washington 98104.

Introduction: As the field of Astrobiology is rapidly expanding from habitability assessments to biological detections, astrobiologists are in search of evidence for "life as we don't know it" through biosignatures. In order to search for potential biosignatures, the geologic record of a planet must be considered [1]. Therefore, both disciplines of planetary geology and astrobiology must collaborate to establish the conditions that make up an effective biosignature and determine how they can measure those biosignatures of samples through various instrument techniques that can be included in future planetary missions for life detection purposes. In doing so, the first part of this research project, "What does it take to make a biosignature?" strives to investigate what biosignatures can serve as evidence for potential extraterrestrial life through the forms of educational modules that can be used in a high school setting.

The second part of this research project, "Associating geobiological measurements with biogenic and abiotic features" analyzes how to use different types of instrument techniques. These techniques can examine the biogenicity of samples from Mars-analog field sites and Europa ocean-ice interfaces. The purpose of this paper is two-fold. First, we will show the development of the Geobiological Handbook of Measurements for Life Detection (GHMLD). Secondly, we will illustrate how this handbook outlines the usage of instrument techniques to measure evidence of biological processes.

Motivation: When searching for evidence of extinct and/or extant extraterrestrial life, astrobiologists face many challenges in establishing effective biosignatures. For example, biosignatures recognized on Earth can be produced abiotically, meaning with no presence of life [2]. Because of this, some biosignatures can provide false positives in the detection of life. Another challenge astrobiologists encounter is that they only have terrestrial life as a reference point to consider what features are biotic and abiotic. Terrestrial life on Earth evolved based on the climate, environment, chemistry, and geology of our planet. These factors can greatly differ within other habitable planets such as Europa or Enceladus [2]. These challenges are addressed in the educational modules with the purpose of communicating the importance of incorporating both disciplines of planetary geology and astrobiology in the search for evidence of extraterrestrial life when establishing conditions that make up an effective biosignature.

When searching for biosignatures in future planetary missions, it needs to be considered how to utilize a variety of instrument techniques to effectively measure for physical biosignatures and chemical biomarkers [2]. With the GHMLD, planetary geologists and astrobiologists can utilize these instrument techniques and their indicated measurements to search for potential physical biosignatures or chemical biomarkers outside Earth.

Literature & Methodology: In order to develop the educational modules for the research project "What does it take to make a biosignature?", there were three steps. The first step was to conduct research on the relevant literature based on the given topic of each module. The second step was to develop a report from the research literature itself and lastly translate the information presented in the report through a "Science Nugget". A "Science Nugget" is a one-page snapshot that summarizes the research conducted for the report of each educational module. The significance of a science nugget is to visually display the key ideas from a written report or a scientific paper. In doing so, the information from reports or papers is easily accessible in one place.

To transition to the educational modules, for the second part of the research project, "Associating geobiological measurements with biogenic and abiotic features", the GHMLD was developed. This project was conducted in a series of four steps. First off, instrument techniques of interest that were to be included in the handbook were identified. From there research on the literature on those instrument techniques was conducted. After, the research was organized in a geobiological measurements database. Once the database was completed, it led to the development of the handbook.

Instrument Modules: In order to answer the question, "What does it take to make a biosignature?", three topics were developed for the educational modules in the form of Science Nuggets. The first Science Nugget informs about the types of biosignatures found in the rock and mineral record on Earth. The second Science Nugget outlines the past, current, and future Mars exploration missions. Lastly, the third Science Nugget

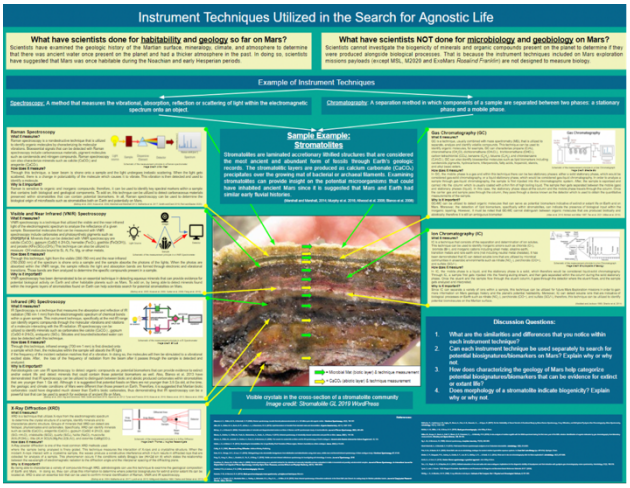

Fig. 1. Science Nugget #3 "Instrument Techniques Utilized in the Search for Agnostic Life".

examines instrument techniques that can be utilized to search for agnostic life (Fig 1). This science nugget brings together the information presented in the first and second science to demonstrate the instrument techniques that have been utilized to detect biosignatures on Earth and to examine the habitability and geologic history of Mars [3]. The third science nugget also explores how various instrument techniques such as Raman spectroscopy can be possibly used to examine the geobiology and microbiology potentially present on Mars [4] (Fig 2).

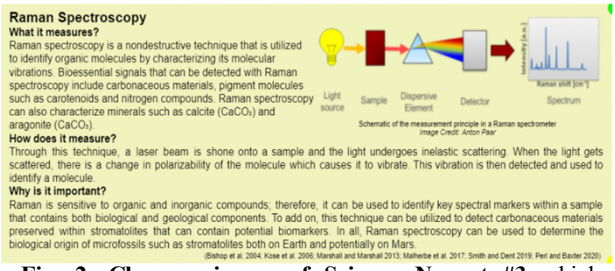

Fig. 2. Close-up image of Science Nugget #3 which demonstrates how Raman spectroscopy can be used to measure the biotic and abiotic features of a stromatolite.

Generating the Geobiology Handbook for Life Detection: Since it is important to consider the payload that will be included in future planetary missions to search for extraterrestrial life extinct and or extant life, the third science nugget greatly correlates to the GHMLD [2]. The handbook examines four important topics of interest for each instrument technique. The physics of what's being measured in each instrument were analyzed, meaning what the instrument is doing to the sample. The resolution of each instrument technique and the sample medium and volume needed to measure with the given instrument technique was researched. Lastly, the capabilities for life detection for each instrument technique were investigated. Through the GHMLD, it informs the readers that not all instruments measure biology, however, they can be coupled together to identify potential physical biosignatures or chemical biomarkers. In order to obtain a positive detection of biogenicity in a sample, an instrument must be sensitive enough to measure a sample with adequate volume that is enough to measure potential biological processes.

Integration with NASA Education: The purpose of the educational modules and the GHMLD is to inform the public of the need to bridge together the fields of planetary geology and astrobiology to search for evidence of extinct and or extant extraterrestrial life. Specifically, the "Science Nuggets" were designed to be utilized at the high school level and are accompanied by discussion questions that will engage students in open-ended discussions of the topics presented in each module. In doing so, everyone has access to the information to contribute to the conversation to search for potential evidence of life on habitable planets and icy moons.

Future Plans: To transition to the final phase of this research project, it is planned to publish the findings in a peer-reviewed manuscript for the Astrobiology Review Category: "Associating Geobiological Measurements with Biogenic and Abiotic Features". It is also scheduled to meet with the NASA Headquarters education office and the Exobiology Program to publish the GHMLD. Lastly, to extend the research conducted to the general public, meetings with the JPL Education Office will be implemented for the wider distribution of the GHMLD.

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