Isothermal Heat Conduction Calorimetry for In Situ Detection of Extant Life. C. Youngbull[1], S. Shkolyar[2], A. C. Hatch, E. L. Shock, A. D. Anbar, [1]Arizona State University, Biodesign Institute, Tempe, AZ 85287 acy@asu.edu, [2]Arizona State University, School of Earth & Space Exploration, Tempe, AZ 85287

Introduction: Current approaches to life detection make assumptions about what that life is like, usually very much shaped by life-as-we-know-it. Here, we propose isothermal calorimetry as a generic, minimal-assumption approach to life detection. The application of calorimetric measurements to quantify biological reactions is pervasive in food science, agriculture, and biotechnology, but is as yet unexplored for the purpose of in situ life detection on other worlds. Isothermal heat conduction calorimtry has already proven useful for studying whole organisms and cellular processes in hyperarid soil [1],[2]. Micofabricated nanocalorimeters have been reported for the monitoring of the metabolism and specific activity of small populations of cells [3],[4] and even single cells [5].

We present a nanocalorimeteric approach, designed to definitively locate and characterize extant chemotrophic or organotrophic life with high sensitivity. The premise is that death, growth, replication, structure formation and biomolecular processing, any of which are fundamental to life's definition, will have a thermodynamic response to applied perturbation. Moreover, we hypothesize that the thermodynamic response is distinguished from anticipated abiotic enthalpy and between different types of extant metabolizers, defining a *thermodynamic fingerprint* of extant life. The use of perturbation-induced response calorimetry addresses the potential of life existing in a dormant or hibernating condition. Even with limited available knowledge of the chemical makeup of the hypothesized Martian soil we anticipate the ability to determine the presence of life and, with foreknowledge of a supplied perturbation, to classify the extant metabolism of that life into metabolic and environmental condition-classes or clades.

Based on a differential signal between sample and reference thermopile sensors, the nanocalorimeter in development operates with minimal volume, weight and power requirements. The differential isothermal calorimeter measures thermal power (P) by operating in the quasi-static mode $\Delta P = Ps - Pref = K\Delta T$ limit since the events to be measured take place on time scales much longer than the thermal relaxation time constant of the calorimeter. Since events to be detected are very slow, time averaging is employed to further reduce the minimum detectable power. The sensitivity and stability of the measurement fixes the minimum power that can be detected. Taking the metabolism of living cells as an example, their dissipated heat is known to range from 1 to 300pW [1],[6]. Advanced nanocalorimeters regularly perform with nanowatt noise levels using microliter volumes which implies a few tens of cells per microgram can be measured [7]. This is not far from the reported bacterial density in hyperarid Atacama Desert soils, where densities begin at a few tenths of a single bacterium per microgram [8].

It is envisioned that most perturbation induced responses will be triggered by delivery of reagents into a thermally isolated volume. Other possible perturbations include exposure to electromagnetic fields, heat, gases, radioactive particles and more. In situ reagent delivery is accomplished using a pre-pressurized delivery system held at a small positive gage pressure. Reagents are selected to cover a broad range of toxic and nutrifying conditions to perturb and induce thermodynamic chemical responses in the extant soil. The energy production resulting from these thermodynamic processes will be detected using low power, low noise embedded microelectronics. Calibration of the device is based on introducing both exothermic and endothermic chemical reactions that exhibit a predictable change in enthalpy. A prototype instrument is currently being used in the laboratory to monitor live cells in the presence of either natural or synthetic substrates, with or without perturbation.

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