A SULFUR-BASED GLACIAL ECOSYSTEM AS A MODEL FOR THE HABITABILITY OF EUROPA AND MARS. K E Wright¹, D F Gleeson¹,2, C Williamson³, S E Grasby⁴, J Spear⁴, R T Pappalardo² and A S Templeton³. ¹Department of Geological Sciences UCB 399, University of Colorado at Boulder, Boulder, CO 80309 USA, email: katherine.wright@colorado.edu ²Jet Propulsion Laboratory, California Institute of Technology, Mail Stop 183-301, Pasadena, CA 91109, USA ³Environmental Science and Engineering, Colorado School of Mines, Golden, CO USA, ⁴Geological Survey of Canada, Natural Resources Canada, Calgary, Alberta, Canada

Introduction: At Borup Fiord Pass Glacier in the Canadian High Arctic, seasonal springs of near-freezing water arise through a glacier, and deposit large quantities of elemental sulfur on the ice. We have evidence that this is due to the activities of sulfur-cycling microorganisms, and that sulfur redox reactions are the dominant energy source for this microbial ecosystem. This unique site therefore provides an excellent terrestrial analogue for studying the potential for life, and how life might be detected, in sulfur-rich icy environments on other planetary bodies, in particular Europa and Mars.

Discussion: Each summer, new deposits of elemental sulfur appear on the glacier in Borup Fiord Pass in the Canadian High Arctic as a result of the action of seasonal springs (see Figure 1). The spring water is rich in both sulfide and sulfate [1] and the microbial population in the environment of the springs is dominated by non-photosynthetic sulfur-metabolizing bacteria [2]. There is no volcanic or hydrothermal activity in the area, and we have evidence that the elemental sulfur is produced as a result of microbial metabolism [3]. As far as we know, nowhere else on Earth can we find such significant quantities of microbially-produced sulfur in a non-volcanic glacial environment.

Figure 1: Elemental sulfur on Borup Fiord Pass Glacier, July 2009.

The hypothesis that we are testing is that sulfur cycling in this unique environment is dominated by biological rather than abiotic processes, and that sulfur-redox reactions are the dominant energy source for primary production.

Sulfur as an energy source for life.

Microbial redox metabolism of sulfur-containing compounds is a common energy-generating mechanism. In oxic environments, the oxidation of hydrogen sulfide through to sulfate by oxygen is thermodynamically favorable [4]. In the absence of oxygen, alternative oxidants such as Fe³⁺ can be used in order to obtain energy [5, 6]. Microbes have also been shown to be capable of using disproportionation reactions, where the same sulfur compound is both oxidized and reduced, in order to obtain energy [7]. This type of reaction eliminates the need for a separate oxidant and reductant, and so may be particularly important in non-terrestrial environments where there may be fewer interfaces between oxidizing and reducing conditions than on Earth.

Both Europa and Mars have the potential for sulfur-metabolizing microbial life, as there is evidence for liquid water and sulfur-containing minerals in both places. On Europa, spectroscopic analysis of deposits on the surface of the ice suggest the presence of hydrated sulfate [8] and the subsurface ocean may contain a habitable environment [9]. Martian surface rocks include sulfur-containing minerals [10,11] and thermodynamic modeling shows that, even with the very low levels of oxygen found in the Martian atmosphere today, the oxidation of sulfide to sulfur provides sufficient energy for microbial growth, and may be the most abundant chemical energy source present [12].

Field and laboratory studies to date

Field work at Borup Fiord Pass Glacier in July 2009 provided new geochemical data on the sulfur compounds which are present in the spring water, and in the surface deposits. Sulfide, thiosulfate and sulfate were detected in the anoxic spring water at the point at which it emerges from underground. The surface deposits contain both elemental sulfur and sulfate. This data is being used to assess the thermodynamic potential of sulfur compounds in this ecosystem, by calculating the energy that is potentially available from sulfur redox reactions, and how this varies across the site. We are combining this information with molecular methods to determine which microbes are present at the site, and to look for the presence of genes known to be involved in sulfur redox reactions. We are using
environmentally-relevant culturing techniques to enrich for microbes utilizing different sulfur-redox reactions to obtain energy for growth, to try to identify key sulfur redox reactions that are actually being used in this environment. We have cultures of Borup Fiord organisms oxidizing sulfide to elemental sulfur, oxidizing elemental sulfur to sulfate, and oxidizing thiosulfate to sulfate. We are characterizing these cultures to identify the microbes in each case which are responsible for carrying out these reactions. We are also studying how the products of biologically-mediated sulfur redox reactions differ from abiotic processes. Together these studies will provide valuable new information on the habitability of icy sulfur-rich environments on other planetary bodies, as well as potential biomarkers for life that may exist there.

References: