Meta Analysis of Bacterial Communities in Sulfate Rich Crusts and the Implications for Astrobiology on Mars. J. R. Jacobs[1,2], C. L. Marnocha[2], and J. C. Dixon[2], [1]University of Central Arkansas, 201 Donaghey Ave Conway, AR 72035, [2]Arkansas Center for Space and Planetary Sciences, 202 Old Museum Building, University of Arkansas, Fayetteville, AR 72701.

Introduction: Diverse bacterial communities have been observed in terrestrial rock coatings and sulfate-rich environments. Sulfate deposits of jarosite and gypsum have been discovered on Mars by rover and satellite [1-3]. Phylogenetic data from various Mars analogs selected for this study contain analysis of bacterial communities in sulfate rock coatings, sulfate soil crusts, and sulfate soil found near/in springs.

In this study, phylogenetic data from various Mars analog sites were analyzed and compared to one another. The meta analysis demonstrates the diversity of bacterial communities in a range of extreme environments.

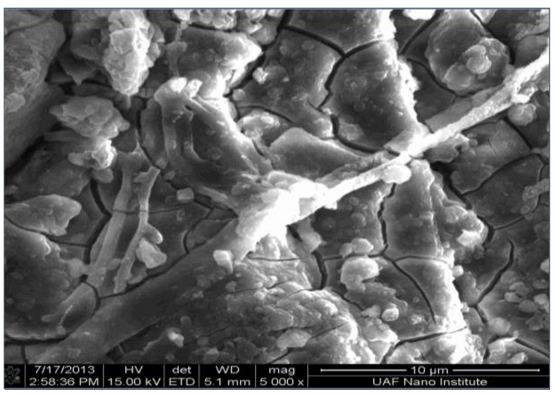

Figure 1: Example of bacterial activity (in the form of a bacterial stalk) in a sulfate crust from Kärkevagge, Sweden.

Methods and Sample Sites: Studies of microbial community sequencing of sulfate-rich environments were selected to be meta analyzed. These studies consisted of bacterial communities in rock coatings, sulfate soil crusts, and soil samples from sulfate-rich springs. The bacterial communities were analyzed at the phylum level. The bacterial communities were compared with the other sites based on abundance of unique and shared phylum. The relative abundance of predominant phyla between sites, phyla shared with four or more sites, was also compared.

Kärkevagge, Sweden. Kärkevagge is a glacially eroded valley located in Sweden [4]. The study conducted at Kärkevagge contained analysis of bacterial communities in sulfate rock coatings. The sulfates that dominate this study site are jarosite and gypsum [5]. Kärkevagge is a relatively acidic environment with a pH of 4.5-8.4 [6], a low mean annual temperature of -2° C, and a total annual precipitation of ~800mm [4].

Atacama Desert, Chile. The study conducted at the Atacama Desert contained analysis of bacterial communities in sulfate soil crusts with gypsum being the dominate sulfate. The study site is relatively basic with a pH 7.9-8.1 and it has a mean annual temperature of 15° C. [7] The interesting characteristic of this site is that it is a hyperarid environment with an annual rainfall of ~12 mm [8,9].

Cuatro Ciénegas Basin, Coahuila, Mexico. The Cuatro Ciénegas study is another which involves sulfate-rich soil crusts of gypsum. The soil samples collected were near a spring and dessicated lagoon. The pH of the study site is 8.5-8.8 and has a annual precipitation of <150mm. [10] Temperatures in the basin range from a minimum of -2° C to a maximum of 55° C [11].

Homestake Gold Mine, Lead, South Dakota. The samples from this study were from sulfate rich soils, mostly in the form of SO_4 ions, from a mine. One characteristic of the mine that makes it interesting for bacterial growth is the lack of sunlight. Average temperature data for the mine is not available but the temperature when the samples of this study were collected was 26° C. The site also has a near neutral pH of 6.6-6.7. [12]

Axel Heiberg Island, Canada. Axel Heiberg Island is located in the Canadian High Arctic. The samples collected in the study at Axel Heiberg were soil samples from a spring. The spring is high in sulfate concentration with a pH of 6.9-7.5. Temperatures in the spring range from -0.5° C to 6.9° C. [13]

Paint Pots, Kootenay National Park, Canada. Paint Pots is located in the Kootenay National Park in Canada. The samples in this study were collected from soils in acidic springs, and soils around the springs. The springs are natural iron-sulfate system and have a pH ranging from 2.88-4.19. Source of sulfides are due to pyrite and sphalerite. Water in the spring during the time of the study was 3.8° C, and average air temperature was ~23° C. [14]

El Coquito, Colombian Andes. El Coquito is an acidic hot spring located in the Colombian Andes. The most abundant ions in the spring are sulfate ions and the spring has an acidic pH of 2.7. Average water temperature of the spring is 29° C, and air temperature around the spring can fluctuate between -4° C and 50° C in a day. [15]

Results: The sample site that showed the highest abundance of unique phyla was Lead, South Dakota (70.7%). The sites at Kärkevagge and Axel Heiberg Island contained no unique phyla compared to the other sites. The only phylum that was found in every site was Proteobacteria. Proteobacteria was the most abundant in six out of the seven sites. The dominant phylum in the Atacama Desert was Actinobacteria. Axel Heiberg Island only contained three out of the seven predominant phyla and Paint Pots had five out of the seven. All other sites contained every one of the predominant phyla.

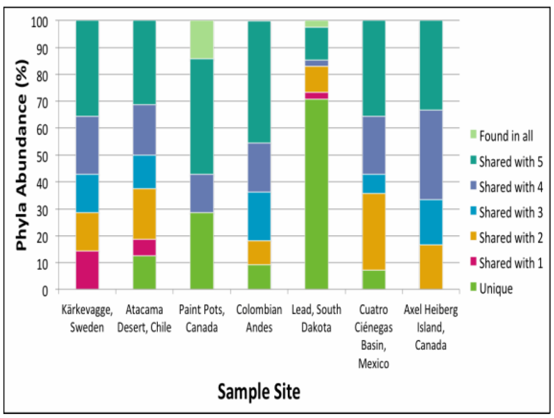

Figure 2: Distribution of shared phyla between sites for this selected study

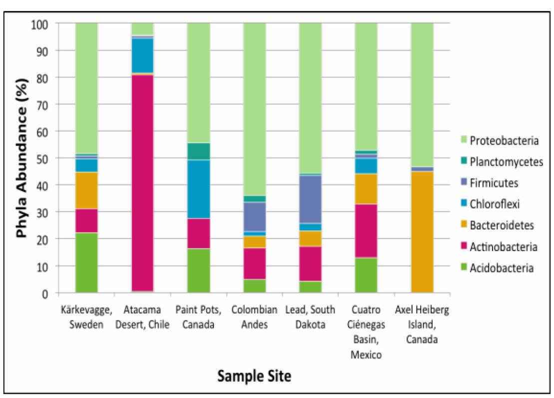

Figure 3: Relative abundance of dominant phyla for each site

Conclusions: The most interesting thing that this meta analysis shows is sulfate bacterial communities are capable of growth and development in various extreme conditions in these Mars analog sites. The distribution of phyla among the sites show that some contain unique phyla while others are shared with one, two, more, or all sites. This displays the diversity of the bacterial communities in these extreme environments. While these sites do contain diverse communities there are still phyla that are found at most sites, predominant phyla. The fact that these phyla are found in arid, hot, cold, acidic, and saline environments show that they can adapt and live in many different types of climates and habitats. The dominance of Actinobacteria in the Atacama suggests less diversity in hyperarid environments.

Chloroflexi was found in largest amounts from the sulfate soil crust samples. The only soil crust site where Chloroflexi was not abundant was at the Lead, SD site. The samples from Lead, SD were taken from a mine which contains no sunlight, making it not a very suitable habitat for Chloroflexi, a photohetertrophic organism.

In comparing collected sequences to databases, a higher number of basepairs can better discern between isolates contained in the database. Thus, more basepairs can yield higher specificity in assigning taxonomy. As a result, those field sites which sequenced greater ranges of the 16S gene were often associated with novel phyla.

Sulfate bacterial communities are of importance to astrobiological research due to the sulfates that have been observed on Mars. Due to their metabolism, bacteria in these communities have the capability to biomineralize sulfates. These environments are then associated with bacteria, with the thought that these sulfate coatings, soils, and crusts are made from biomineralization. The sulfate deposits on Mars could have arised from microbial facilitation.

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