The fieldwork funded by the Lewis and Clark field research grant was undertaken at Karkevagge, Swedish Lapland (68°26'N, l8°18'E), a glacially eroded, classically U-shaped valley (Figs. 1, 2). Karkevagge is of astrobiological interest as a strong mineralogical and limited environmental analog to Mars. The valley is home to ubiquitous rock coatings, which are the focus of this study. Rock coatings are biologically intriguing targets as they provide a surface environment for life on Mars, afford protection from radiation at the surface, and are an environment conducive to the preservation of microbial biosignatures.

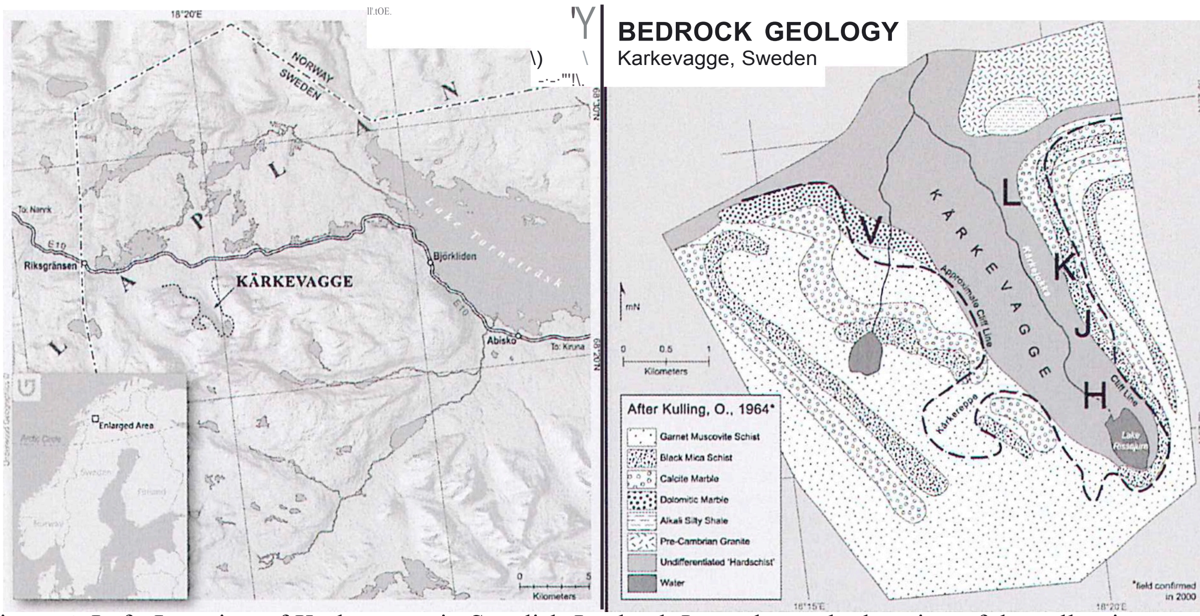

Figure 1. Left: Location of Karkevagge in Swedish Lapland. Inset shows the location of the valley in greater Scandinavia. Right: Bedrock geology and sampling sites (J, K, L, etc.) of Karkevagge.


Figure 2. Karkevagge looking north, illustrating the classic u-shape of the valley and the two large rockfalls that dominate the valley floor.

Rock varnish has been well studied in terrestrial environments for its applications to astrobiology since observations by Viking of putative varnish on the surface of Mars *(1).* It is thought that associated microbial communities are capable of participating in the genesis of the varnish and therefore, could provide abodes for past or present life on Mars *(2-5).*

The rock coatings sampled during the August 2012 field season were sampled along transects developed by Rapp *(6)* and include Fe/Mn films, sulfate crusts, and aluminum glazes (Fig. 3). The primary minerals in the coatings are: goethite and hematite in Fe/Mn films, gypsum and jarosite in sulfate crusts, alunite and basaluminite in aluminum glazes (7, *8).* Goethite, hematite, gypsum, jarosite, and alunite have all been detected by observational satellites and/or Mars Exploration Rovers at multiple locations on Mars *(9-17).* Despite the interest in rock varnish, other coating types have been largely ignored, despite their compatibility with martian mineralogy. Thus, we suggest the rock coatings of Karkevagge as astrobiological targets that warrant further investigation.

Figure 3. Left: Typical presentation of a sulfate (jarosite) crust on a boulder face. Right: An especially thick Fe/Mn film from the eastern side of the valley.

A previous field season (2010) and lab investigations revealed the presence of bacteria in all three coating types, with evidence (through scanning electron microscopy) of the encrustation of cells on coating surfaces, especially in Fe/Mn films. This field season was used to acquire additional coating samples, particularly from the previously undersampled western side of the valley. Subsamples ofthe previous described coating types were collected from the sample sites indicated in Fig. 1. Three samples of each coating type, with each of three representing a different field site, were sent to Research and Testing Lab (Lubbock, TX) for DNA extraction, 454 pyrosequencing of the bacterial 16S gene, and data processing. The software program, *mothur,* was used for subsequent data analysis *(18).*

Preliminary analysis shows great diversity across all three coating types, with a statistically significant difference in community structure as a function of coating mineralogy (P<0.01). The greatest species richness and diversity were observed in sulfate crusts, with lowest richness and least diversity in Fe/Mn films. Nevertheless, all coating types combined had Simpson's Index ofDiversity (1-D) of< 0.14, suggesting very diverse communities.

Fifteen phyla were represented across all nine samples and ten of those phyla were present in all coating samples (Fig. 4). Within the proteobacteria phylum, a-, p-, y-, and ::-*proteobacteria* were all represented, with *a.-proteobacteria* the most common. *a-proteobacteria* was the dominant phyla for two Fe/Mn film samples, two aluminum glaze samples, and one sulfate crust sample. For combined coating types, *a-proteobacteria* was represented in the greatest percentage. Cyanobacteria were more common by far in sulfate crusts than Fe/Mn films or aluminum glazes. *Acidobacteria* and *Actinobacteria* were also well-represented phyla in all coating types.

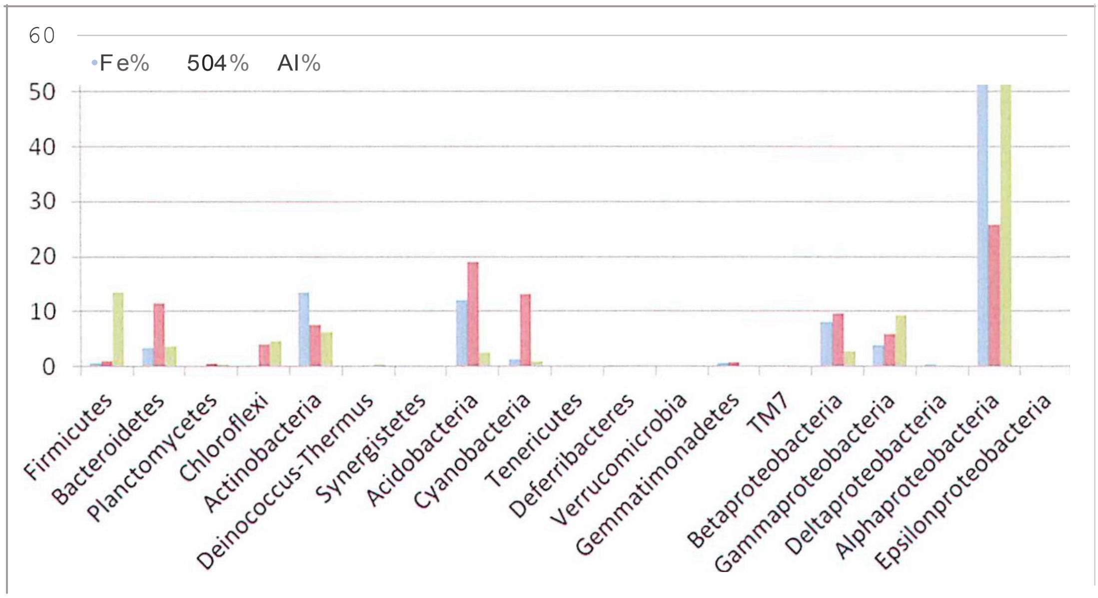

Figure 4. Percentage of phyla represented by coating type.

The work funded by this grant has contributed significantly to the current understanding of the bacterial communities in rock coatings from Karkevagge. Future work will involve the use of coating material as culture inoculum in an effort to reproduce biomineralization. The additional fieldwork and pyrosequencing analysis have provided a framework for identifying potential biosignatures in rock coatings that could be applied to current and future Mars miSSIOnS.

References

I. E. L. Strickland, in *Lunar and Planetary Science Conference X.* (1979), vol. 10, pp. 3055-3077.
2. B. E. DiGregorio, in *Proceedings ofSPIE.* (2002), vol. 4495, pp. 120.
3. R.I. Dorn, Rock Varnish. *Geochemical Sediments and Landscapes,* 246 (2007).
4. D. Krinsley, R. I. Dorn, B. DiGregorio. *Astrobiology* 9, 551 (2009).
5. R. Mancinelli, J. Bishop, in *Lunar and Planetary Science Conference XXXlll*. (2002), vol. 33, pp. 1046.
6. A. Rapp. *Geografiska Annaler* 42, 65 (1960).
7. R. G. Darrnody, C. E. Thorn, J. C. Dixon. *Geological Society of America Bulletin* 119, 1477 (2007).
8. J. C. Dixon, C. E. Thorn, R. G. Darrnody, S. W. Campbell. *Geological Society of America Bulletin* 114, 226 (2002).
9. J.-P. Bibring *eta!. Science* 307, 1576 (2005).
10. J.-P. Bibring *eta!. Science* 312, 400 (2006). II. A. Gendrin *eta!. Science* 307, 1587 (2005).
12. G. KlingelhOfer *eta!. Science* 306, 1740 (2004).
13. G. KlingelhOfer *eta!.. !CAME 2005,* 549 (2007).
14. S. W. Squyres *eta!. Science* 306, 1709 (Dec 3, 2004).
15. A. Wang *eta!. Journal of Geophysical Research* **111,** (2006).
16. P. Christensen *eta!. Journal of Geophysical Research* 105, 9623 (2000).
17. G. Swayze *eta!.,* in *American Geophysical Union, Fall Meeting 2008.* (2008).
18. P. D. Schloss *eta!. Applied Environmental Microbiology* 75, 7537 (2009)