Environment and Natural Resources Trust Fund
2009 Phase 2 Request for Proposals (RFP)

LCCMR ID: 043-B1

Project Title: Scientific and Commercial Discoveries from Soudan Iron Mine

Total Project Budget: $ $523,140

Proposed Project Time Period for the Funding Requested: July 2009 - June 2012

Other Non-State Funds: $ $0.00

Priority: B1. Reduce Soil Erosion

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Region:	County Name:	City / Township:
NE	Anoka, Hennepin, St. Louis	

Summary: The bottom level of the Soudan Iron Mine is a unique environment in Minnesota. We will study the microbiology, geochemistry and mineralogy and identify potential commercial applications (bioremediation, bioenergy, drug-discovery).

Main Proposal: 1008-2-003-proposal-Soudan Geomicro.pdf

Project Budget: 1008-2-003-budget-LCCMR Budget 2.pdf

Qualifications: 1008-2-003-qualifications-Gralnick Qual & Org LCCMR.pdf

Map:

Letter of Resolution:

MAIN PROPOSAL

PROJECT TITLE: Scientific and Commercial Discoveries from Soudan Iron Mine

Using Ancient Bacteria to Tackle Modern Problems – Bioremedation, Bioenergy and Drug Discovery from the Soudan Iron Mine

I. PROJECT STATEMENT

The study of extreme or novel environments can sometimes lead to discoveries that change the world. In the early 1970's such a discovery was made in hot springs in Yellowstone National Park – bacteria thriving at temperatures previously thought to be inhospitable for life were identified. The commercialization of proteins from these bacteria revolutionized science, enabling an era of modern molecular genetics, including sequencing of the human genome, and is the foundation of a multi-billion dollar biotechnology industry. Based on our preliminary analysis, a similar commercial opportunity will be found deep underground in Northern Minnesota at the bottom of an abandoned iron mine.

The Soudan Iron Mine near Ely, MN closed in 1962 and later became the Soudan Underground Mine State Park. The Soudan Mine is both a historical site, offering the public an opportunity to reflect on past economic activities and technologies of the iron range, and also houses the High Energy Physics Lab, administered by the University of Minnesota. This state park attracts around 40,000 visitors per year; making it an important destination for both residents of Minnesota and surrounding states.

The lowest level of the Soudan Mine is home to an extraordinary environment where the fields of microbiology, geochemistry and mineralogy converge. The sedimentary iron-rich rock that was mined for 80 years at this site is known as a 'Banded Iron Formation' or BIF. BIFs contain a significant portion of the iron found on the surface of our planet, and the Soudan BIF is estimated to be around 2.7 billion years old. Typically, oxygen is required to form rust (as we all know well in Minnesota), however the Soudan BIF was deposited ~ 400 million years before oxygen was present in significant amounts in our atmosphere. Geomicrobiologists have suggested that iron-oxidizing bacteria could have been responsible for these ancient sedimentary formations. What about today?

In the lowest level of the Soudan Iron Mine water seeping from boreholes drilled in the waning days of the mine can be found. This water is quite unusual since it is almost three times saltier than seawater and is devoid of oxygen. Associated with many of these seeps are unique iron oxide structures and throughout this strange water are poorly characterized iron minerals and thriving bacterial communities. The bacteria we have analyzed so far from this environment appear to be distant relatives of bacteria commonly found in the ocean. What are bacteria from the ocean doing in water found 2341 feet underground in northern Minnesota? Are descendants of organisms that helped form the Soudan BIF still living in waters trapped within the iron formation?

The unique environment of the lowest level of the Soudan Mine presents many exciting opportunities directly related to LCCMR funding priorities (Water Quality – Reduce soil erosion). Mining activities, both abandoned and current, can mobilize toxic metals from deep underground into our surface waters. Bacteria studied from the Soudan Iron Mine may be used to more effectively treat contaminated water from this, and potentially other active mining sites throughout the state. Research proposed here will help us develop a basic understanding of the microbiology, mineralogy and geochemistry of the mine. We will explore possible commercial applications deriving from microbes analyzed from the mine. **This work could lead to exciting new areas of research and potential revenue for the State of Minnesota in the areas of bioremediation, bioenergy and drug discovery.** Finally, a public outreach program will be developed to educate visitors and also protect this unique natural resource.

II. DESCRIPTION OF PROJECT RESULTS

Result 1: Microbiology, Minerology and Geochemistry – Basic Science **Budget: $355,140**

The microbiology section will focus on identifying and categorizing the microbial populations found in the mine. The mineralogy portion will focus on synchnotron-enabled analysis of both structure and composition of minerals found in the Level 27 brine and on samples from iron formations. The geochemistry analysis will focus on chemical and isotopic characterization of the Level 27 brine, in addition to heavy metal analysis on Level 10 (and elsewhere in the mine as directed by the DNR).

Deliverables:	**Completion Date**
1. Molecular phylogenetic analysis of microbes	June 30, 2012
2. Mineralogical, speciation and elemental analysis	June 30, 2012
3. Isotope analysis of level 27 brine, gas composition, geochemistry	June 30, 2012

Result 2: Commercial Opportunities – Bioremediation, Bioenergy, Drug Discovery **Budget: $168,000**
In this section we will determine the feasibility of microorganisms isolated from the Soudan Iron Mine in three specific commercial areas. Our priority here is to identify potential commercial assets deriving from microbes cultivated from the Soudan Mine. All DNR regulations will be adhered to and the Office of Technology Commercialization will help facilitate agreements. The Center for Applied Research and Technology Development at NRRI (UMN-Duluth) will also play a key role in this process.

Deliverables:	**Completion Date**
1. Isolate and characterize bacteria that promote oxidation of toxic metals	June 30, 2012
2. Demonstrate the use of iron oxidizing bacteria in microbial fuel cells	June 30, 2012
3. Screen microbial (bacterial and fungal) isolates for novel compounds	June 30, 2012

Result 3: Public Outreach at the Soudan Underground Mine State Park **Budget: $20,000**
Drs. Gralnick, Toner, Bond and Alexander will develop a training module for DNR tour guides to describe the features, microorganisms, biogenic mineralogy and geochemistry within the mine. In collaboration with the DNR and NRRI we will also generate an interactive display in the visitor center to educate visitors about this unique place in the context of microbiology, mineralogy and geochemistry.

Deliverables:	**Completion Date**
1. DNR microbiology training module	June 30, 2010
2. Interactive Soudan mine microbiology display	June 30, 2011

III. PROJECT STRATEGY AND TIMELINE

A. Project Partners

Dr. Brandy Toner (Co-PI) is responsible for all mineralogical analyses. She is a new Assistant Professor at the University of Minnesota (Soil, Water and Climate) with extensive experience working with synchrotron-based analysis of biogenic and natural minerals.

Dr. Calvin Alexander is a Morse-Alumni Professor at the University of Minnesota (Geology and Geophysics) and is responsible for all geochemical and isotopic analyses.

Dr. Don Fosnacht (NRRI, UMN – Duluth), Director, Center for Applied Research and Technology Development, has agreed to consult on both commercial and outreach aspects of this proposal.

James Essig (DNR, Park Manager – Soudan Underground Mine State Park) will help coordinate research trips to the mine, outreach activities on site and future commercialization possibilities.

Dr. Daniel Bond (University of Minnesota) is an Assistant Professor of Microbiology and an expert in the area of microbial fuel cells and bacterial metal reduction.

Dr. Christine Solomon (University of Minnesota) is the co-director of the Center for Drug Design. She will screen pure-culture isolates for production of medically relevant compounds.

B. Project Impact

This project will provide important insight into a unique environment in the Soudan Iron Mine. A fundamental understanding of this unique environment will be gained, and several exciting potential applications will be explored and commercialized. Our outreach program will enrich the educational experience for visitors to the mine and will supplement the History and Physics Lab attractions currently available at the state park.

The Soudan Underground Mine State Park currently the treats water from some mine levels for elevated metals. Research proposed here will help quantify biological metal mobilization in the old mine workings and identify microorganisms that may be beneficial for low cost remediation, both locally at the Soudan Mine and potentially for use at other locations.

C. Time

Three years of funding will be sufficient to accomplish the research (Result 1), explore commercial potential (Result 2) and outreach (Result 3) proposed here.

D. Long Term Strategy

At the end of the three year project, we expect to have obtained results that will support funding from national agencies (such as the National Science Foundation) and we will begin partnering with organizations (such as Natural Resources Research Institute) and local companies to test feasibility of novel bioremediation and bioenergy using bacterial from the Soudan Iron Mine.

Project Budget

IV. TOTAL PROJECT REQUEST BUDGET

** 3 Year, Total Cost **

BUDGET ITEM	AMOUNT	% FTE
Personnel:		
Brandy Toner (Co-PI - 1 month summer salary) - Result 1 - Years 1-3	$ 30,000	8%
UM Scientist (Scott Alexander, 1 month salary / year requested) - Result 1.3 - Years 1-3	$ 13,740	8%
1 Graduate Research Assistant (Soil, Water, Climate, PhD) - Result 1.2 - Years 1-3	$ 108,000	50%
1 Graduate Research Assistant (Microbiology, PhD) - Result 1.1 - Years 1-3	$ 114,000	50%
2 Graduate Research Assistants (A,B - Microbial Engineering, MS) - Result 2 - Years 2-3	$ 128,000	50%
Equipment/Tools: None	$ -	
Acquisition (Including Easements): None	$ -	
Restoration: None	$ -	
Other:	$ -	
Result 1:		
Molecular biology reagents (PCR reagents, DNA extraction kits, plasmid purification kits ($500 ea., 12/year), enzymes, chemicals, microbiology consumables (agar, media), general lab supplies (tubes, tips, gloves etc.) - Micro PhD Student - Years 1-3	$ 30,000	
Laboratory supplies and consumables (chemicals, sample storage, sample preparation, general lab supplies) - SWC PhD Student - Years 1-3	$ 15,000	
Microscopy (SEM, Light - User fees at CBS Biological Imaging Facility)	$ 4,500	
Sequencing for phylogentic analysis of microbial communities (AGAC Sequencing facility on UM campus $7 / reaction, estimate 400 reactions / year)	$ 8,400	
Advanced Photon Source at Argonne National Labs (Chicago - travel, lodging, user fees) for mineralogical analyses	$ 10,500	
Chemical, isotopic and gas analysis (reagents for extraction / preservation, measurements, user facility fees)	$ 30,000	
Publication fees	$ 1,500	
In-state travel to/from mine (+ logding), in/out of mine - estimate 5-6 trips / year	$ 12,000	
Out of state travel to national meetings to present results from this research and to learn from colleagues in other states. American Society for Microbiology General Meeting, American Geophysical Union, Applied and Environmental Microbiology Gordon Conference	$ 7,500	
Result 2:		
Heavy metal quantitation, pure and mixed culture screening for bioreduction, characterization of strains, laboratory consumables for MS student (A) - Years 2-3	$ 10,000	
Bioenergy experiments - electrode maintence, new reactor design for Fe oxidizers, media preparation, laboratory conumables for MS student (A) - Years 2-3	$ 10,000	
Lab supplies for screening experiments in Center for Drug Design - user fee at center for highthrougput screening, purification / characterization costs, laboratory consumables for MS student (B) - Years 2-3	$ 20,000	
Result 3:		
Outreach development (display, content development, education, implementation, consulting fees for design, additional travel to the state park, content updates)	$ 20,000	
TOTAL PROJECT BUDGET REQUEST TO LCCMR	$ 523,140	

V. OTHER FUNDS

Serenity:Users:jeffrey:Desktop:GRANTS:LCCMR:LCCMR Budget 2.xls

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ Being Leveraged During Project Period:	none	
Other State $ Being Spent During Project Period:	none	
Past Spending:	$0	

IV. PROJECT MANAGER QUALIFICATONS & ORGANIZATION DESCRIPTION

Project Manager Qualifications

Dr. Jeffrey A. Gralnick, Project Manager and Principle Investigator

Dr. Gralnick is an Assistant Professor of Microbiology at the University of Minnesota and a member of the BioTechnology Institute, located on the St. Paul Campus. Gralnick was trained in Bacteriology at the University of Wisconsin – Madison where he specialized in microbial physiology. He then spent three years at the California Institute of Technology (Caltech) in the Division of Geological and Planetary Sciences where he studied geomicrobiology – specifically how bacteria interface with minerals. His training in both microbiology and geomicrobiology will help make our interdisciplinary team more cohesive. Please visit his website for further description of research interests and for images from the Soudan Iron Mine:

http://cbs.umn.edu/labs/gralnick/Gralnick_Lab/

Dr. Gralnick is among the first group of Associate Fellows in the University's new Institute on the Environment, based primarily on his vision for educational outreach, dedication to environmental microbiology and ability to blend both basic and applied science in his work. His commitment to education and outreach is demonstrated by his participation in the College of Biological Sciences Nature of Life program for incoming freshmen. He also co-teaches a course for freshman entitled 'Happy in Hell: Microbes in Extreme Environments,' where examples from the Soudan Iron Mine are discussed.

Dr. Gralnick is the Project Manager of this proposal. Though having just completed three years at the University, he has established a solid record of both internal (Institute on the Environment, Institute for Renewable Energy and the Environment, Graduate School, Academic Health Center, Cargill Initiative for Higher Education) and external funding (Office of Naval Research). Importantly, Dr. Gralnick is a member of the University of Minnesota's BioTechnology Institute – an organization designed to help interface academia with industry. These relationships will be key to any future commercialization of technologies or discoveries made by research proposed here.

Dr. Gralnick is on a 12-month appointment through the University of Minnesota Academic Health Center (Home department – Microbiology) and has therefore not requested any salary support.

Organizational Description

The University of Minnesota's mission is threefold: 1) Research and Discovery, 2) Teaching and Learning, and 3) Outreach and Public Service.

The Minnesota Department of Natural Resources- Division of Waters mission is: Helping people ensure the future of our water resources.

Part 4: Maps and Figures

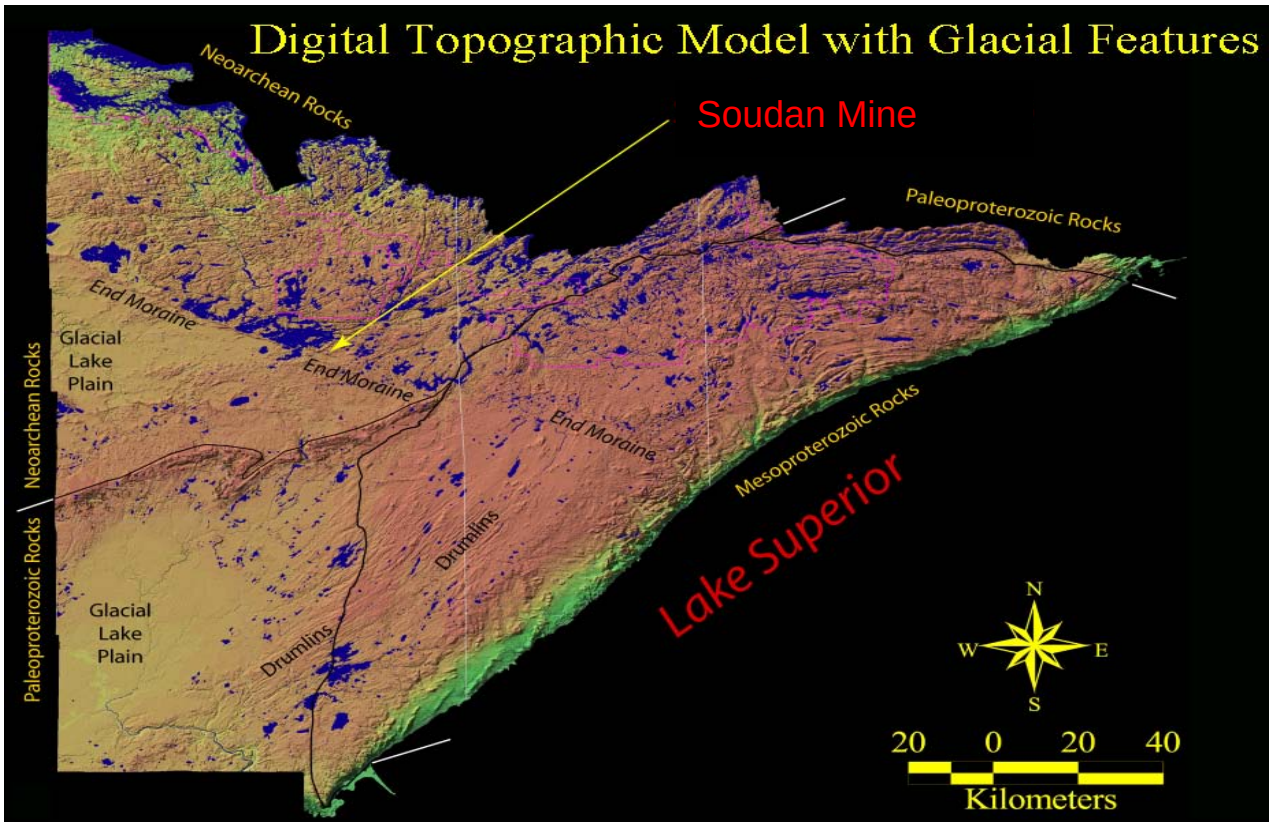

Figure 1. Location Map of the Soudan Mine in Northeastern Minnesota.

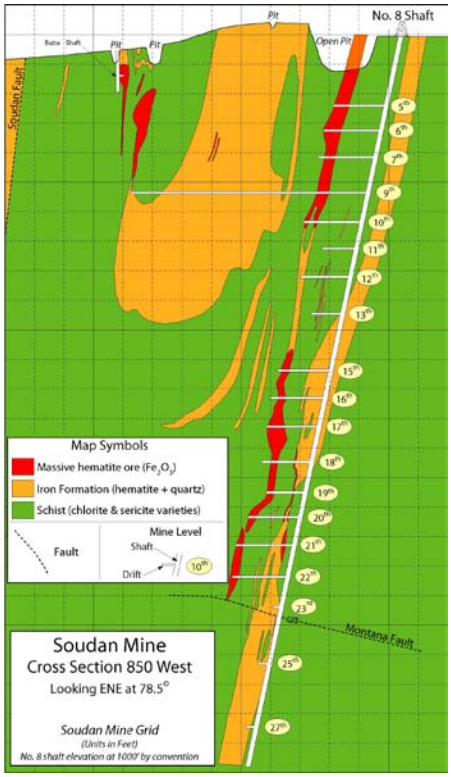

Figure 2. Soudan Cross section.

Figure 3. Biogenic Iron Oxide (Ferrihydrite) "Speleothem" Deposit in the Bottom, 27th Level of the Soudan Mine.