Biomining for In-Situ Resource Utilization

Darin Ragozzine
Harvard University ’03-’05-’04
NASA Institute for Advanced Concepts
Student Visions of the Future Program
Advisor: Dr. Sarah Stewart
Outline

• Concept
• Overview of Biomining and Bacteria
• Extraterrestrial Biomining
• Future Engineering
• Advantages of Space Biomining
• Applications to Potential Space Missions
• Conclusions
Concept Proposal

Use chemolithotrophic bacteria to mine extraterrestrial regolith for metals and other materials needed for In-Situ Resource Utilization.
Overview of Terrestrial Biomining

- Produces over ¼ of the world’s copper
  - Mostly through passive “Heap leaching”
- Pretreat some gold ores (biobeneficiation)
  - Stirred tanks = bioreactors
- Biohydrometallurgy and Geomicrobiology
  - Lots of research and published information
About the Bacteria

- Mostly *Thiobacillus Ferrooxidans*, *Thiobacillus Thiooxidans*, and *Leptospirillum Ferrooxidans*
  - Anaerobic
  - Autochemotrophic
  - Lithotrophic
  - Acidophiles (pH ~2-3)

---

Fig. 14.1. Biofilm of *T. ferrooxidans* on the surface of a sulfur prill. Sulfur prills were colonized by *T. ferrooxidans* for two weeks. After this time, the samples were processed for scanning electron microscopy. The bar indicates 10 μm.
About the Bacteria

• Oxidize Fe(II) and (indirectly?) other metal sulfides
• Oxygen is used as the final electron acceptor
• Need relatively small amount of nutrients
  – Most nutrients are found in ores naturally
  – Carbon can be infused through CO₂ gas
• Studies show that extraterrestrial materials (meteors) are biofriendly
Biomining Flowchart

RAW REGOLITH

PROCESSED REGOLITH

BIOVAT

BACTERIA

METALS IN SOLUTION

SOLVENT EXTRACTION & ELECTROWINNING

DESERVED METALS

WASTE

DROSS

EJECTED (OR REPROCESSED)

TEMP, PH, STIRRING

MACHINE CONTROLLED

OXYGEN

NUTRIENTS

BIOMATERIAL

CHEMICALS

WATER

RECYCLED:

WATER

BIOMATERIAL

CHEMICALS

Darlin Ragozzine
NIAC Student Fellow
March 23, 2004
Future Engineering

• Biological
  – Already begun on Earth, seems fruitful
  – “Space-hardened” bacteria

• Genetic
  – Combine desirable traits from other organisms

• Chemical/Mechanical
  – Create a system that optimizes the biovat

• ECOLOGICAL
  – Create an entire autonomous self-regulating microcosm
Advantages
(over other space-mining concepts)

• Simple
• Nearly autonomous
• Low Power

• Robust
• Modular (small)
• Already Developed

• Multiple Metals can be obtained
• Spinoffs benefit terrestrial biomining as well as geomicrobiological studies
Advantages
(over other space-mining concepts)

• Ideal for colony/base start-up
• Small amounts of metals from “low-grade” ore, i.e., raw regolith:
  – Copper, Cobalt, Nickel, Zinc, Gallium, Molybdenum, Silver, Manganese, Platinum Group Metals, Uranium, etc.
• Disadvantage: throughput is small
• Disadvantage: only certain minerals
Applications to Potential Space Missions

• Extracting metals for ISRU
  – Potentially for the Moon and Asteroids
  – (Bio)mining much better suited to Mars

• Small (1-2 m³) biovats can leach most of metals from sulfide ore in 1-2 weeks

• Optimize based on mission requirements
  – Extracting several “trace” metals from the Moon
  – Autonomous gold/platinum mining on asteroids
  – Copper production plant for Martian base
Applications to Potential Space Missions
Conclusions

• To zeroth-order, concept shows promise
• To first-order, concept is viable and useful
• Further development can begin immediately

Future Study
  – Test bacteria on extraterrestrial meteors
  – Use most recent chemical/minerological data to assess productive capacity
  – Research supporting systems (solvent extraction, regolith collection and pulverization, other potential biological components, etc.)
Acknowledgements

- NIAC Staff
- Dr. Stewart and Harvard University
- Prof. Henry Ehrlich and James Brierley
- NASA Academy at GSFC 2003
- Alan Ragozzine and Ben Dawson
- Family and Friends

Some pictures and information from Biomining, edited by Douglas E. Rawlings. Background image from NEAR satellite.
Contact Information

Darin Ragozzine
Harvard University ’03-’05-’04
Physics and Astronomy & Astrophysics
ragozzin@fas.harvard.edu
Phone: 617-493-6617

A written report will result from this NIAC Student Grant

Darin Ragozzine
NIAC Student Fellow

March 23, 2004