

Desirable features in a bioleaching microbe for in situ resource recovery

Frank F. Roberto
Biological Systems Dept.

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Comanche Spur outcrop (astrobio.net)



Escondida, Chile

www.inl.gov



Bioleaching and biooxidation of hard rock minerals continues to expand

- 25% of world copper is leached biologically
- Substantial amounts of gold liberated from refractory minerals by partial bioleach termed biooxidation
- Other base metals have been leached experimentally using similar processes: nickel, lead, molybdenum, cobalt, and zinc
- A larger range of metals may be feasible: platinum, silver, palladium, gallium, rhodium, lithium and uranium
- Iron and sulfur-bearing oxide minerals can be leached efficiently under acidic conditions without microbes; sulfide mineral leaching is accelerated by microbes

Bioleaching of minerals is a naturally occurring process, that has been exploited by man for thousands of years, and is also the root cause of acid mine drainage

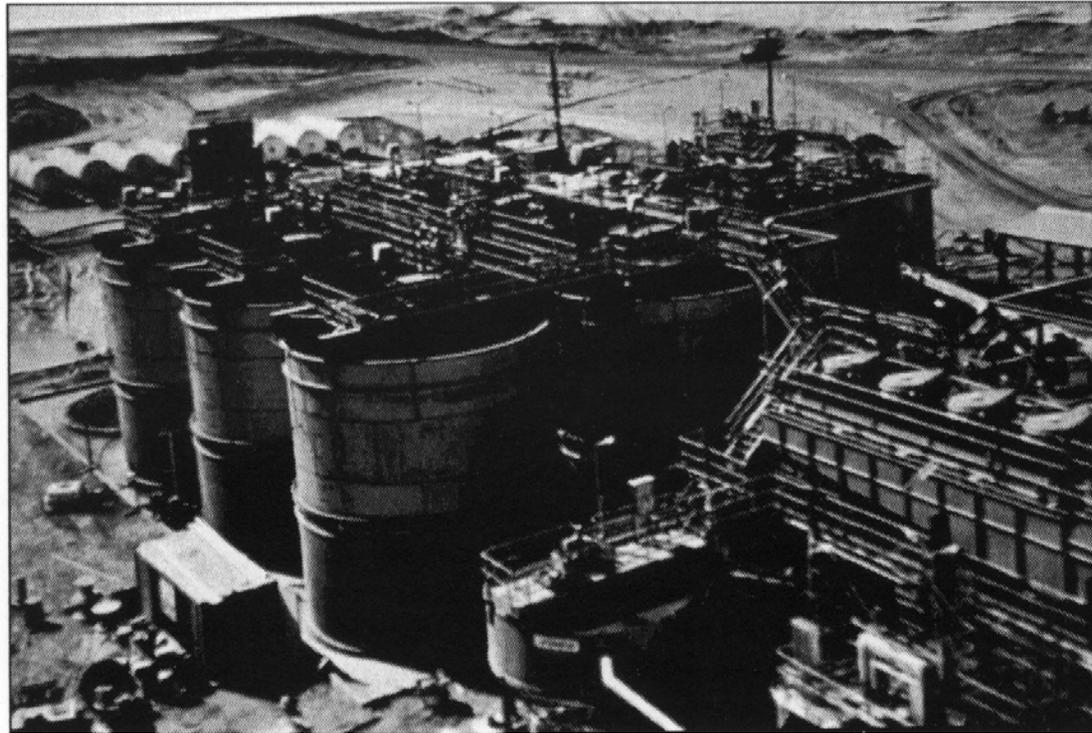


Phoenician-era workings unearthed at Rio Tinto, Spain



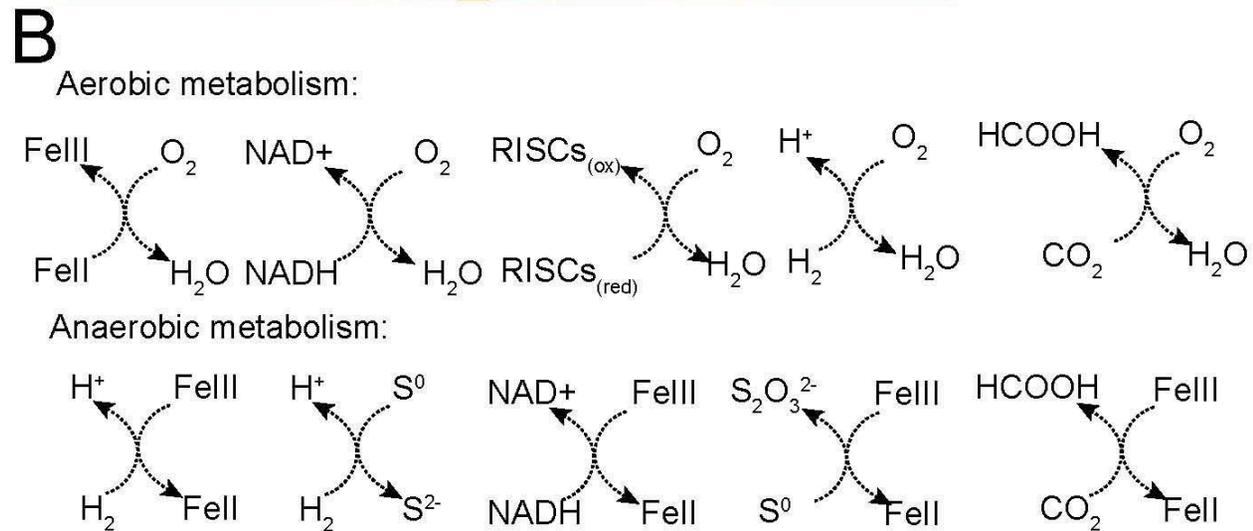
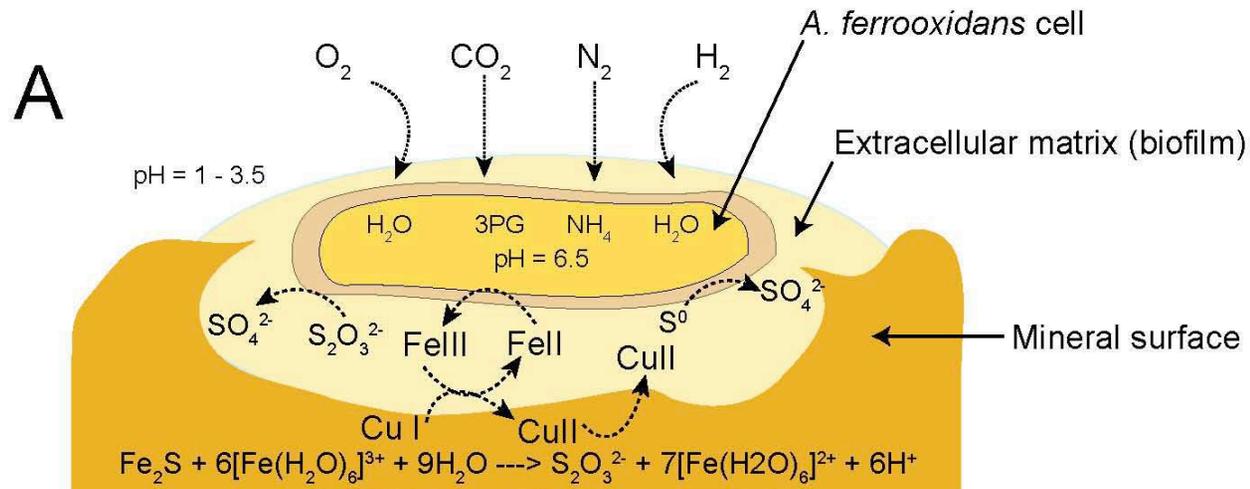
1 million tpd excavation at Morenci Mine, AZ

Bioleaching of sulfide minerals is practiced at phenomenal scale



- **Dump leaching (millions of tons actively being leached)**
- **Heap leaching of copper and gold (17,300 tpd in Chile; Newmont)**
- **BIOX processing of gold concentrates (1000 tpd at Ashanti, Ghana; operating and capital costs less than pressure oxidation at this time)**
- **BacTech moderate thermophile leach of gold concentrate (overcomes some of cooling requirement inherent in BIOX)**

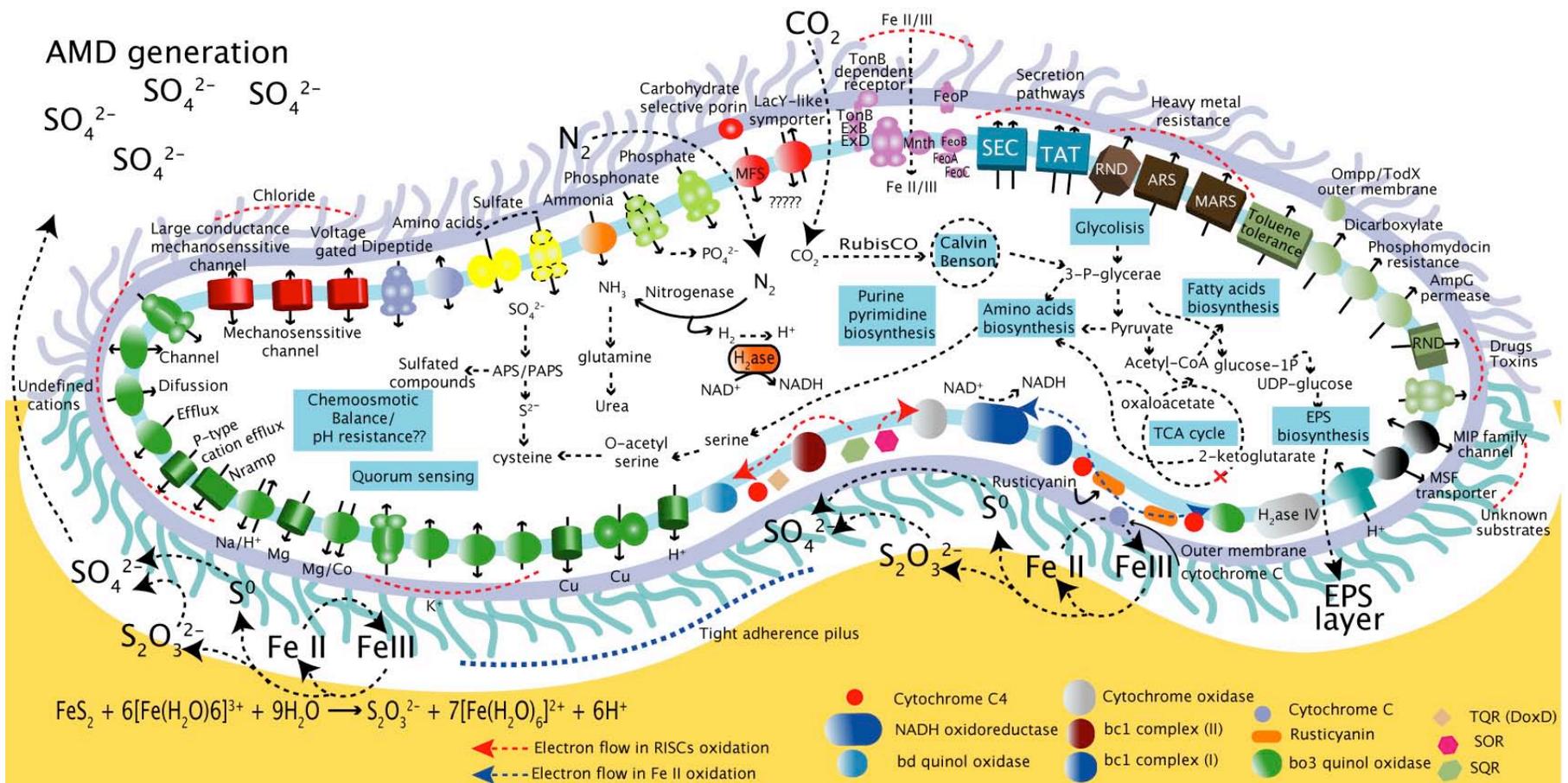
Biogeochemical attack of sulfide minerals



Microbial Challenges (away from Earth)

- Limited H₂O and O₂
- Limited CO₂?
- Functional pH range of 0-4 (Archaea to Bacteria)
- Functional temperature range of 4-90°C (Bacteria to Archaea)
- Radiation (may not be a problem if conducted in subsurface) – linked to desiccation tolerance?
- Toxicity of gangue/heavy metals, other ions – Al, Cr, F, Ag, Pb, As, Hg, Cd, Fe – aggravated by water recycling
- Abrasion – lunar regolith

Acidithiobacillus ferrooxidans functional gene analysis



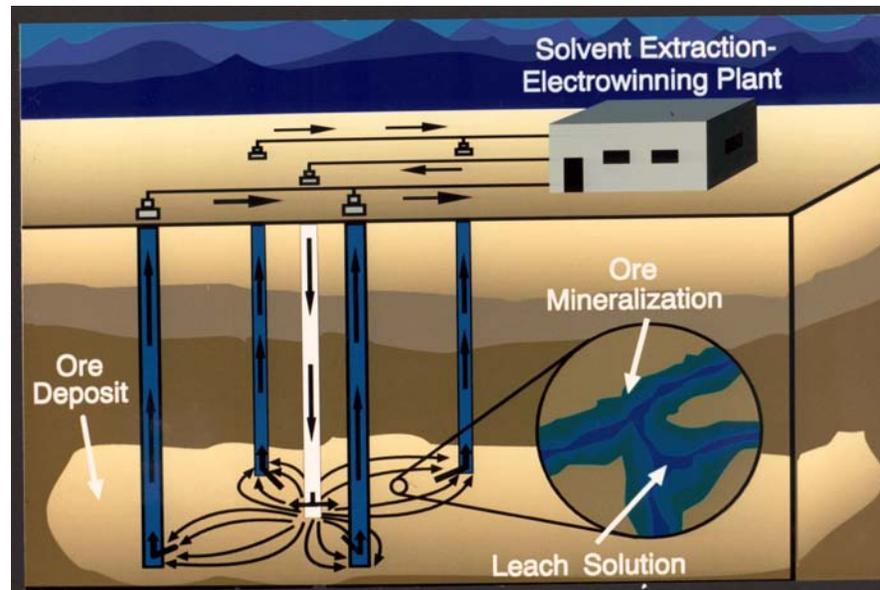
What will an extraterrestrial mining operation look like?



Planets or asteroids



Earth



In situ mine pilot, AZ

Life on Earth always has new surprises



Cinder Pool, Yellowstone National Park