Mars Terrestrial Analogs: the Tinto River case
F. Gómez and R. Amils
Centro de Astrobiología
The Viking Missions concluded that life had little chances to develop on Mars.
Misión MER, Crater Endurance,
What happened between the 30 years that separate both pictures
discovery of:
- extremophiles
- subsurface life
- observationes in the ALH84001
- Pathfinder mission
- discovery of other planetary systems
- development of Astrobiology
H₂O on Mars
EL CAPITAN (MP)
Mössbauer Spectrum of El Capitan: Meridiani Planum Jarosite: $(K, Na, X^{+1})Fe_3(\text{SO}_4)(\text{OH})_6$
water vapor
Methane (PFS)

Black: orbit 145 average ± σ
red 35 ppb methane
MARS CHARACTERISTICS

- hematite ++
- jarosite ++
- goethite +
- ionic strength ++
- temperature surf low
- temperature ss ?
- methane +/-
- oxygene +/-
- µorganisms ?
conclusion: in Mars there are sedimentary rocks generated in aqueous acidic environment

- Possible terrestrial analogs:
  - submarine hydrothermalism
  - acidic environments
  - polar environments
characterized acidic environments:
- volcanic activity areas
  \[ \text{SO}_2 + \text{H}_2\text{S} \rightarrow \text{S}^0 + \text{H}_2\text{O} \]
- sulfidic metal mines
  \[ \text{FeS}_2 + \text{H}_2\text{O} \rightarrow \text{Fe}^{3+} + \text{SO}_4^{2-} + \text{H}^+ \]
Black smokers: tiny minerals settle out of the water around the chimney, they create metal-rich (metaliferous) sediments that appear shiny in this image.

Main Endeavor Hydrothermal Vent Field on the Endeavor Segment of the mid-ocean ridge at 47°57' N, 129°6' W
One of the best-known examples of living halophiles can be found in Shark bay, Australia. The bay is full of *stromatolites*, rocky formations up to 1.5 metres high which were built by colonies of halophile *cyanobacteria*. 
characteristics of the Tinto River

- 85 ppm of Cu
- 195 ppm of Zn
- 379 ppm of As
- 381 ppm of Cr
- 11 ppm of Ni
iron concentration at the origin:
15-20 mg/ml
basic reactions in the Tinto

\[
\text{FeS}_2 + \text{H}_2\text{O} \xrightarrow{\text{O}_2} \xrightarrow{\text{A.F. A.t. L.f. Ferroplasma}} \text{Fe}^{3+} + \text{SO}_4^{2-} + \text{H}^+ \\
\text{Fe}^{3+} + \text{H}_2\text{O} \leftrightarrow \text{Fe(OH)}_3 + \text{H}^+
\]
acidic lake at Peña de Hierro
Iron oxidation bacteria
molecular ecology techniques
DGGE
fluorescence in situ
hibridación

FISH: Leptospirillum ferrooxidans
geomicrobiological model of the Tinto cosystem
iron plays a central role in the Tinto ecosystem

- 80% of the prokaryotic diversity of the system is related with the iron cycle: *Leptospirillum ferrooxidans*, *Acidithiobacillus ferrooxidans* and *Acidiphilium* spp.

- Iron can be used not only as an electron donor in respiration, but also as an electron acceptor in anaerobic respiration, can control the pH (buffer) and can protect from UV radiation and oxidation.
ecological paradox: high level of eukaryotic diversity over a low level of prokaryotic diversity
acidophilic diatoms
acidophilic Protists
Demateaceous fungi
iron bioformations (stromatolites)
iron stromatolites
fossilization of iron
stromatolites
fossil iron bioformations older than $10^6$ years
MARTE project: geomicrobiological exploration of the Tinto subsurface (Pyritic Iberian Belt)
## COMPARISON BETWEEN MARS AND THE TINTO SYSTEM

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<th></th>
<th>MP</th>
<th>RTsurf</th>
<th>RTss</th>
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<tbody>
<tr>
<td>- hematite</td>
<td>++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>- jarosite</td>
<td>++</td>
<td>++</td>
<td>+</td>
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<tr>
<td>- goethite</td>
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<td>++</td>
<td>+</td>
</tr>
<tr>
<td>- ionic strength</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>- temperature surf</td>
<td>low</td>
<td>4-35°C</td>
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</tr>
<tr>
<td>- temperature ss</td>
<td>?</td>
<td>10°C</td>
<td></td>
</tr>
<tr>
<td>- methane</td>
<td>+/-</td>
<td>-</td>
<td>+</td>
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<tr>
<td>- oxygen</td>
<td>+/-</td>
<td>++</td>
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<tr>
<td>- µorganisms</td>
<td>?</td>
<td>++</td>
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</table>
Thanks to the many people that has been working along in the Tinto project for helping to establish the interesting characteristics of this Mars analog.