Mars Terrestrial Analogs: the Tinto River case

F. Gómez and R. Amils
Centro de Astrobiología

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The Viking Missions concluded that life had little chances to develop on Mars

Crater Helas, HRSC

Misión MER, Crater Endurance,

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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

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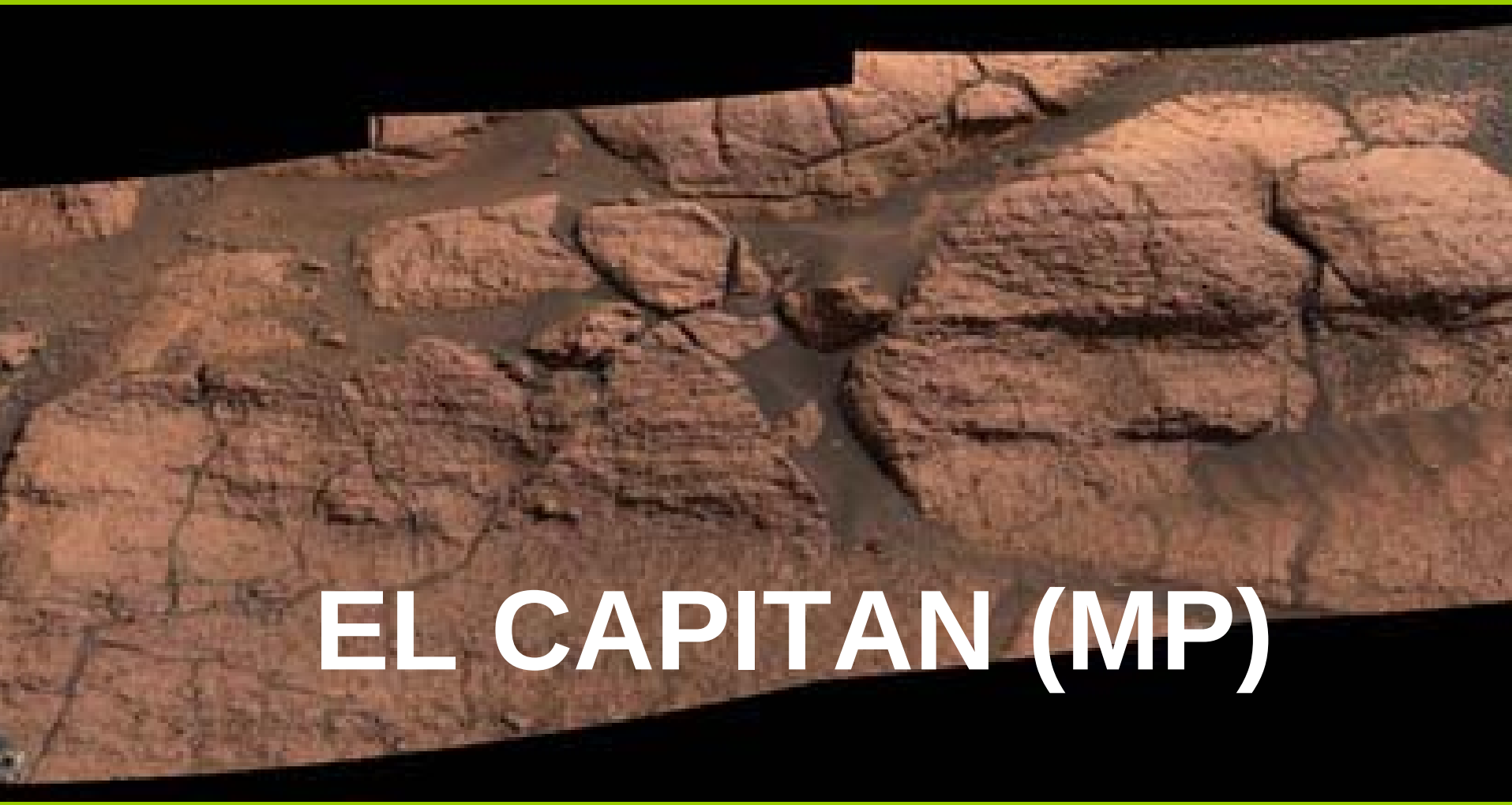
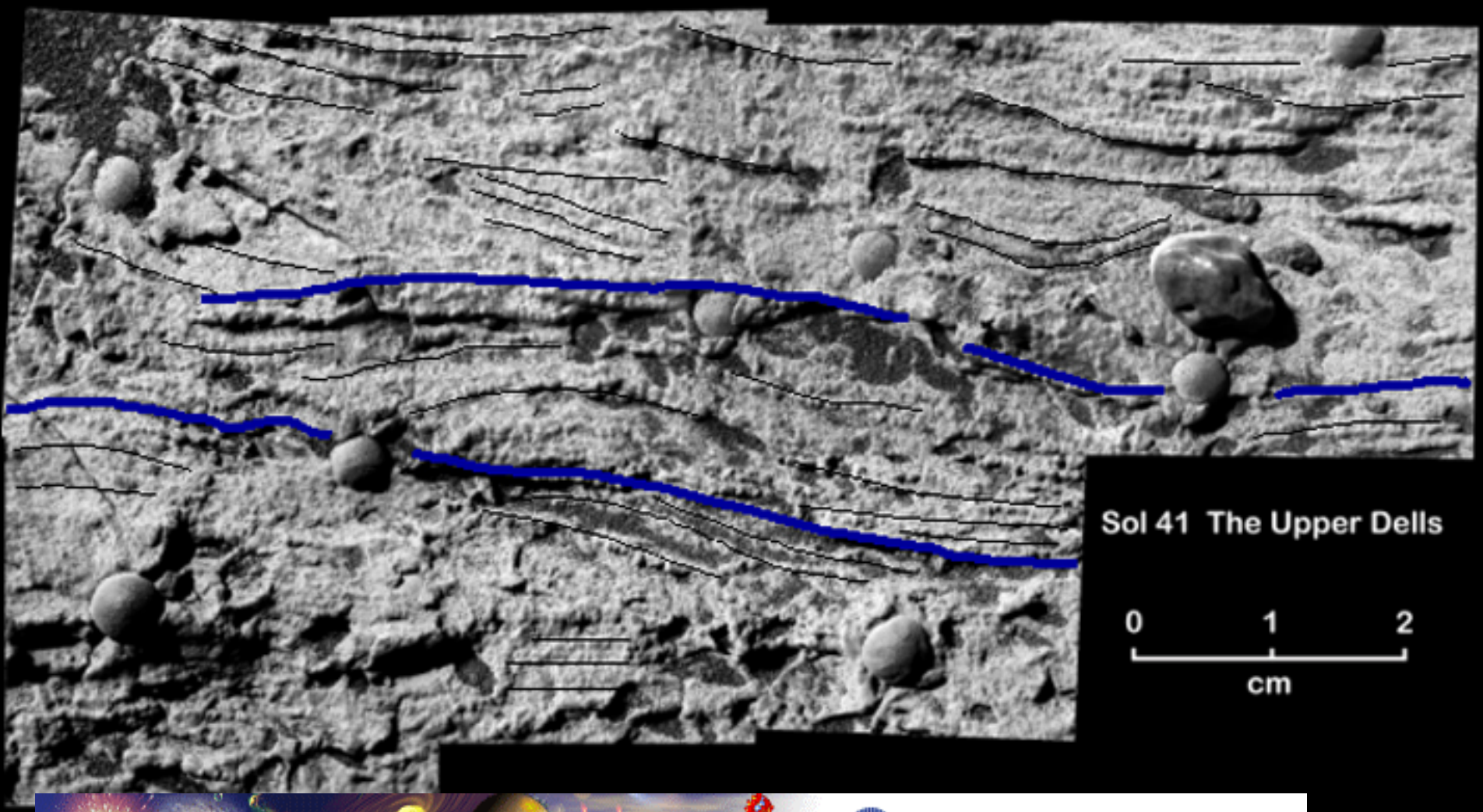
H_2O on Mars



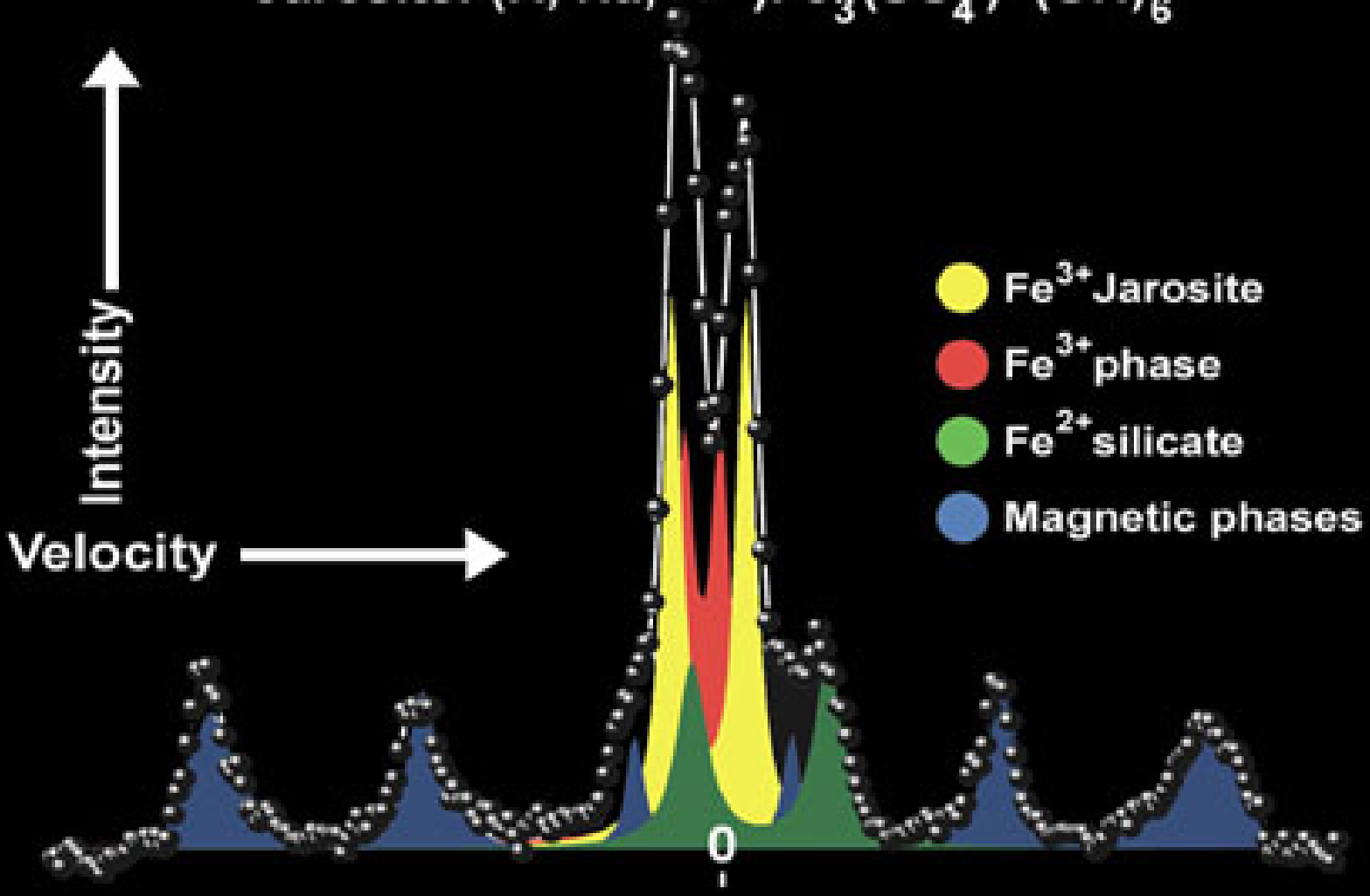
EL CAPITAN (MP)

Upper Dells MI Mosaic



Mössbauer Spectrum of El Capitan: Meridiani Planum

Jarosite: $(K, Na, X^{+1})Fe_3(SO_4)\ (OH)_6$



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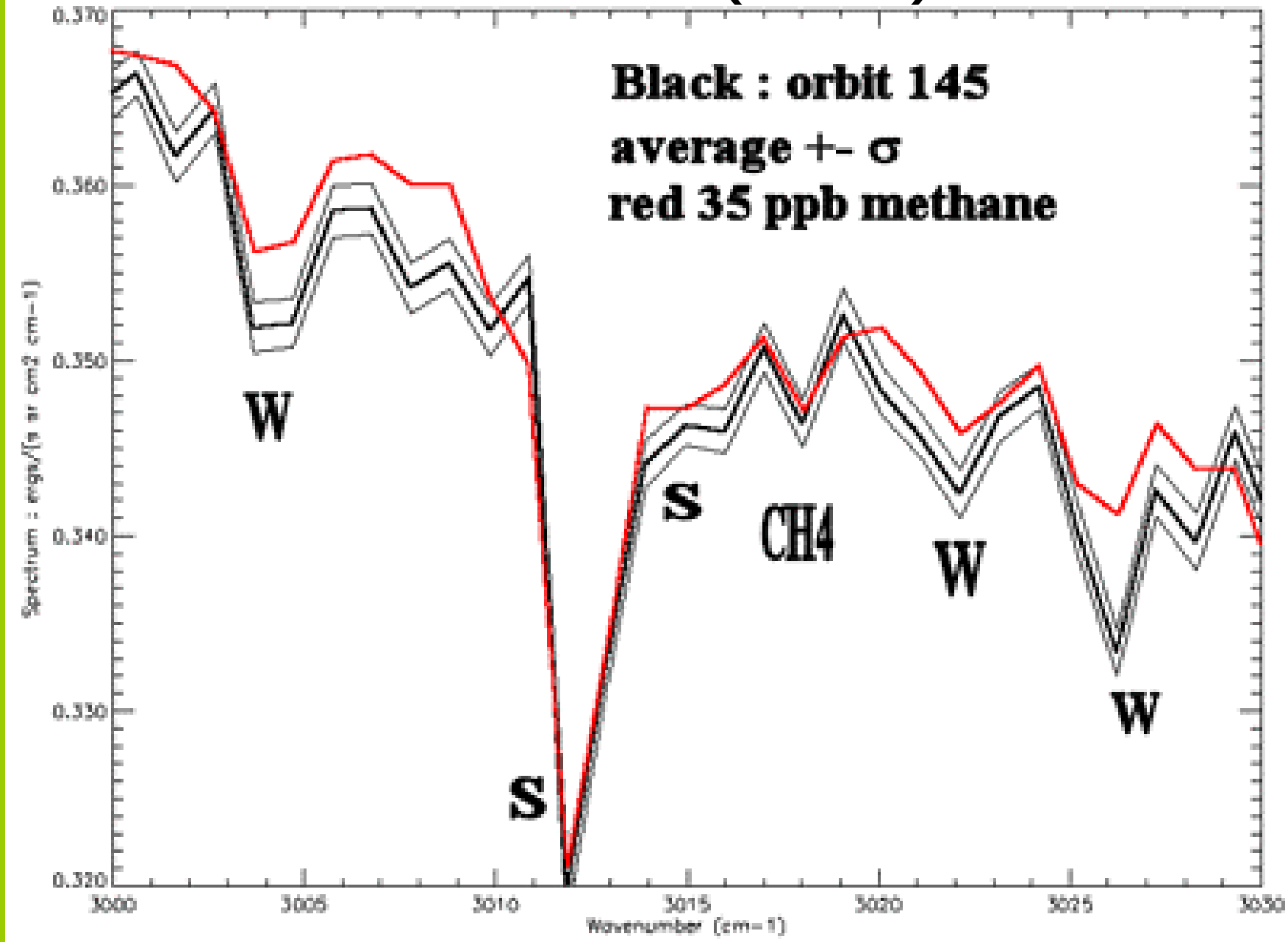
Water vapor

Methane (PFS)


Black : orbit 145
average +- σ
red 35 ppb methane
W
S
CH4
S
W
W
Spectrum : erg/(s sr cm2 cm-1)
Wavenumber (cm-1)
0.370
0.360
0.350
0.340
0.330
0.320
3000
3005
3010
3015
3020
3025
3030

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 environmnents**
  - **polar environments**

characterized acidic environments:

- volcanic activity areas

$$SO_2 + H_2S \longrightarrow S^0 + H_2O$$

- sulfidic metal mines

$$FeS_2 + H_2O \longrightarrow Fe^{3+} + SO_4^{2-} + H^+$$

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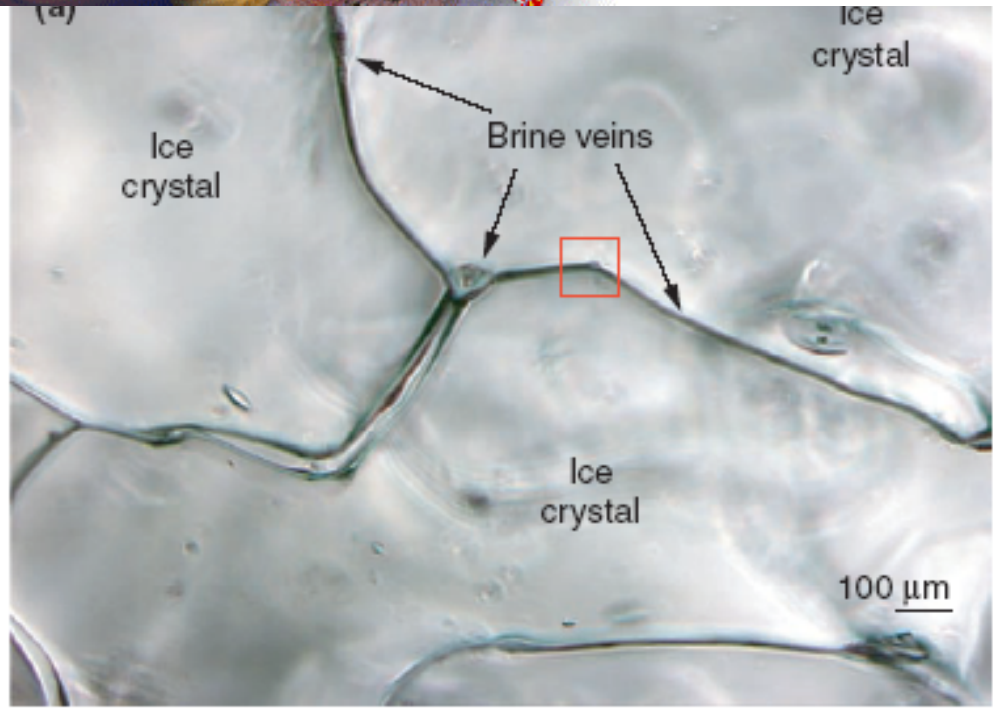
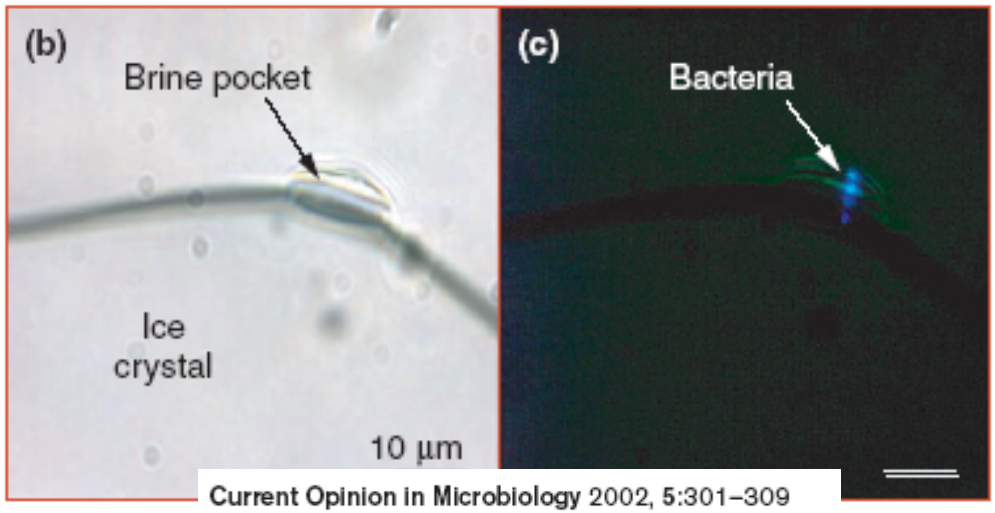
Black smokers: tiny minerals settle out of the water around the chimney, they create metal-rich (metaliferous) sediments that appear shiny in this image.

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**.





Current Opinion in Microbiology 2002, 5:301–309

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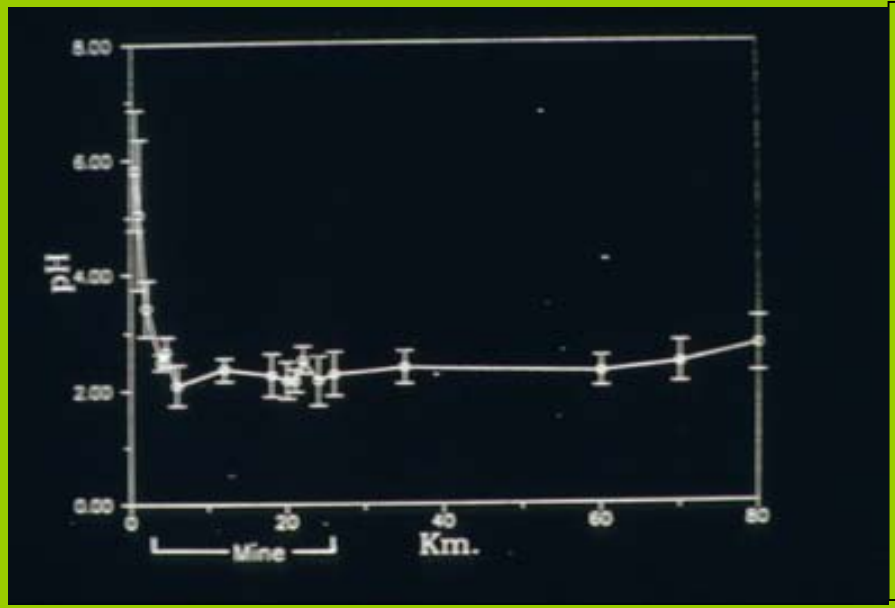
characteristics of the Tinto River



- 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

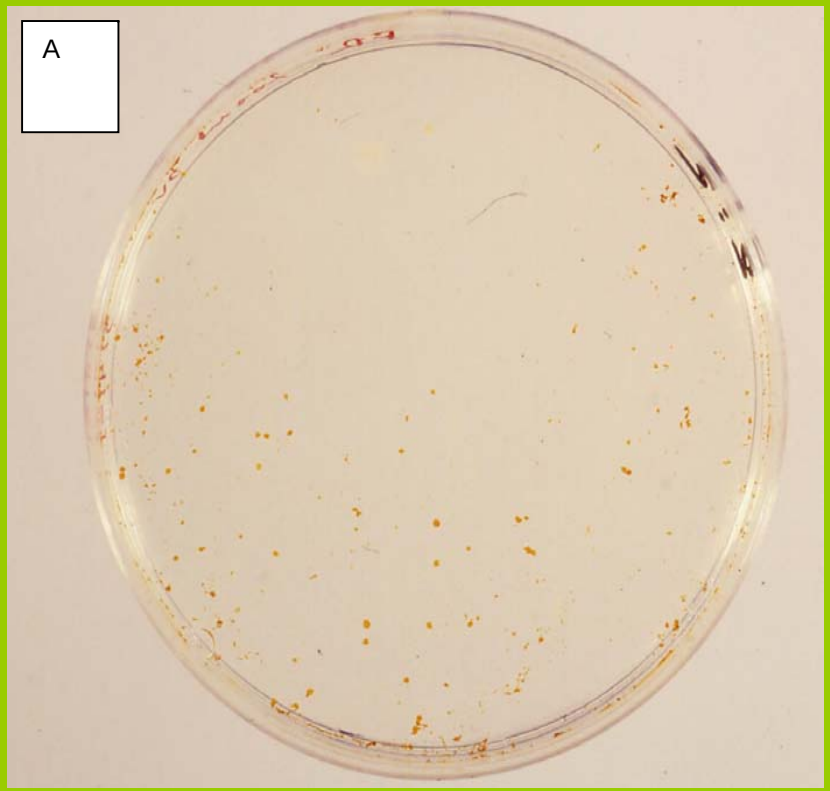
basic reactions in the Tinto

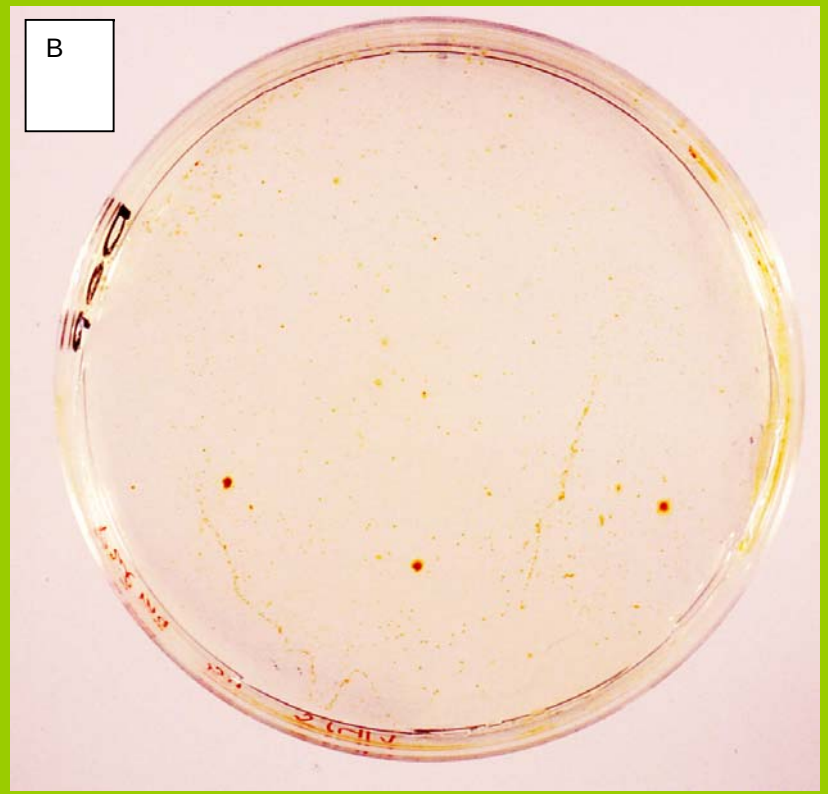
$$FeS_2 + H_2O \xrightarrow[\substack{A.f.\ A.t.\ L.f.\\ Ferroplasma}]{O_2} Fe^{3+} + SO_4^{2-} + H^+$$

$$Fe^{3+} + H_2O \rightleftharpoons Fe(OH)_3 + H^+$$

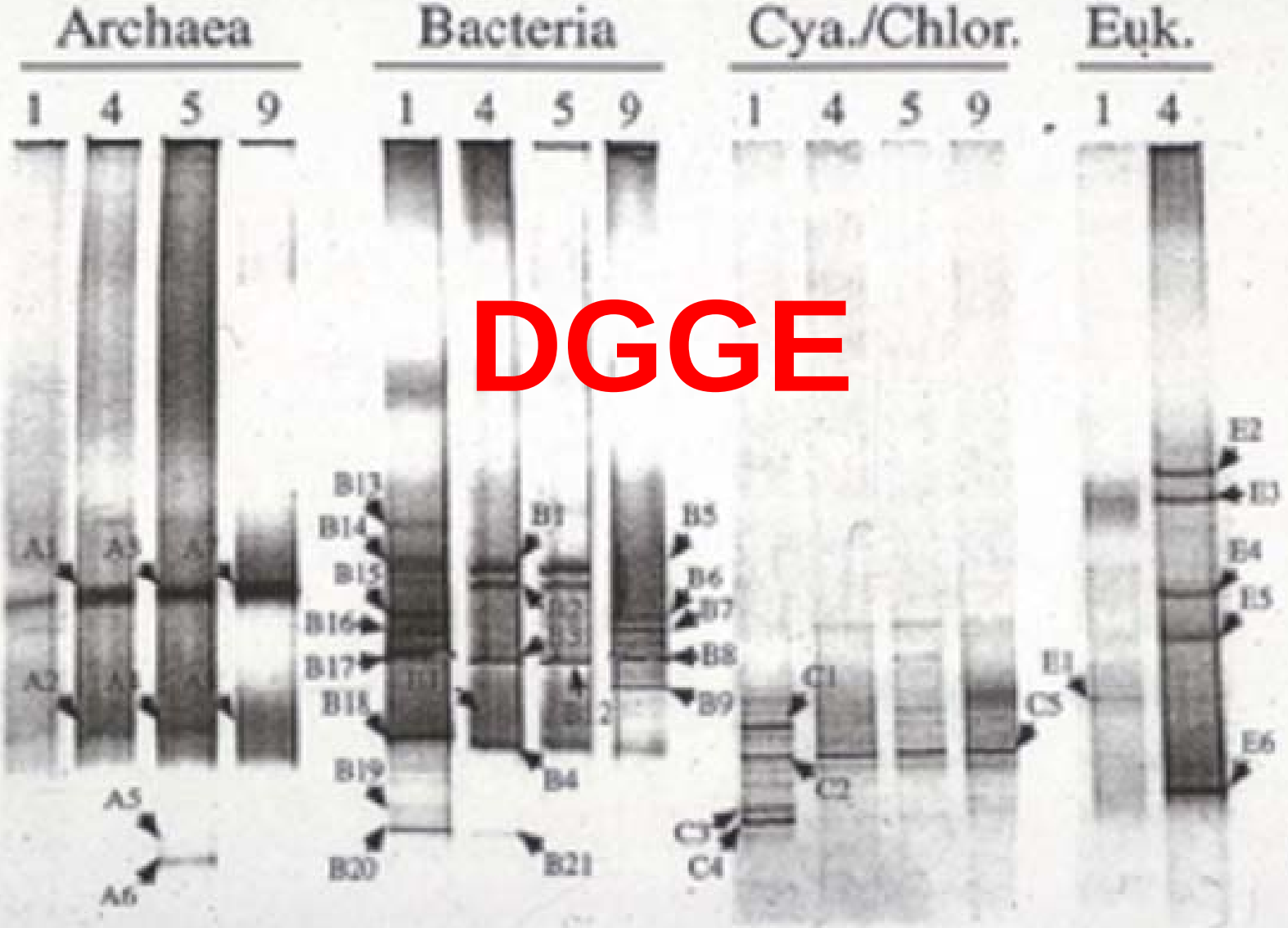
acidic lake at Peña de Hierro

Iron oxidation bacteria

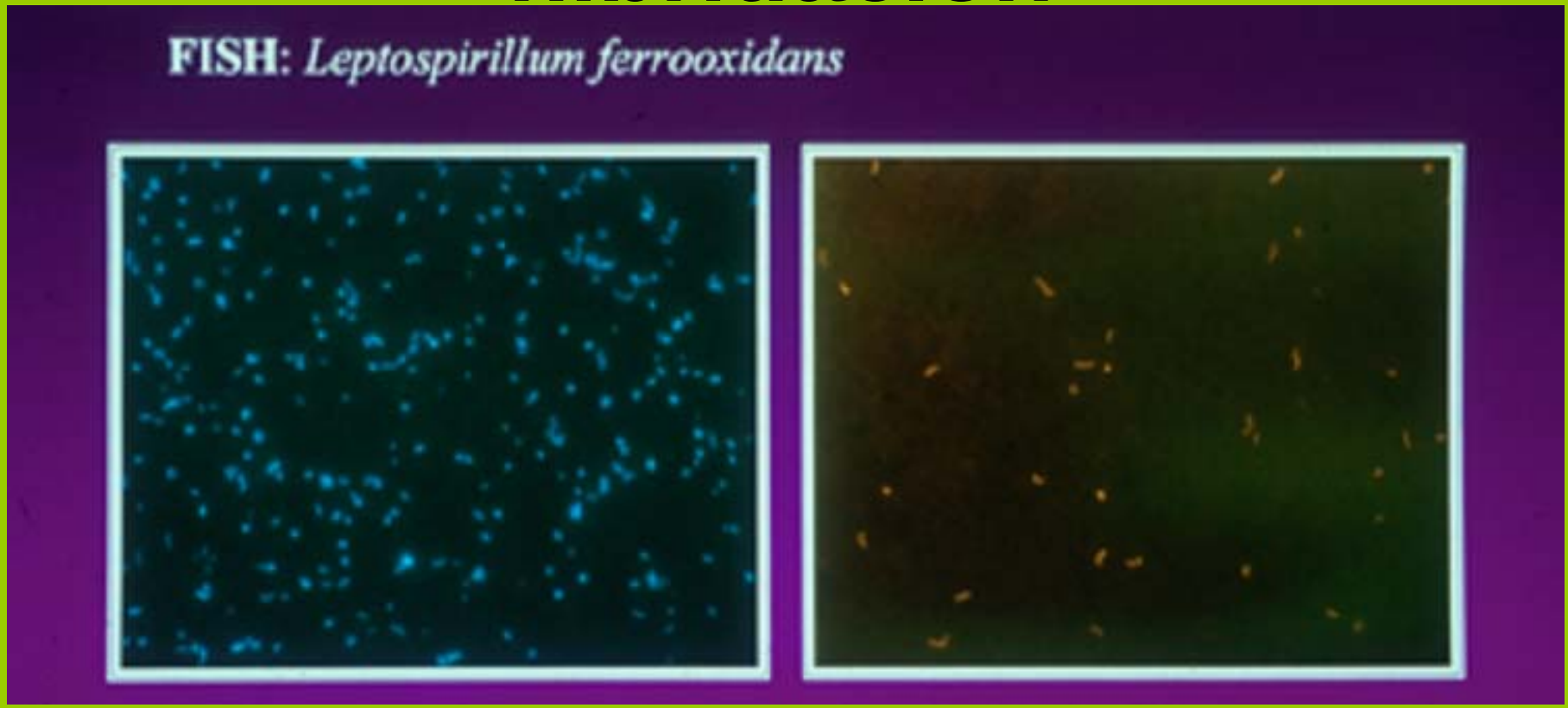




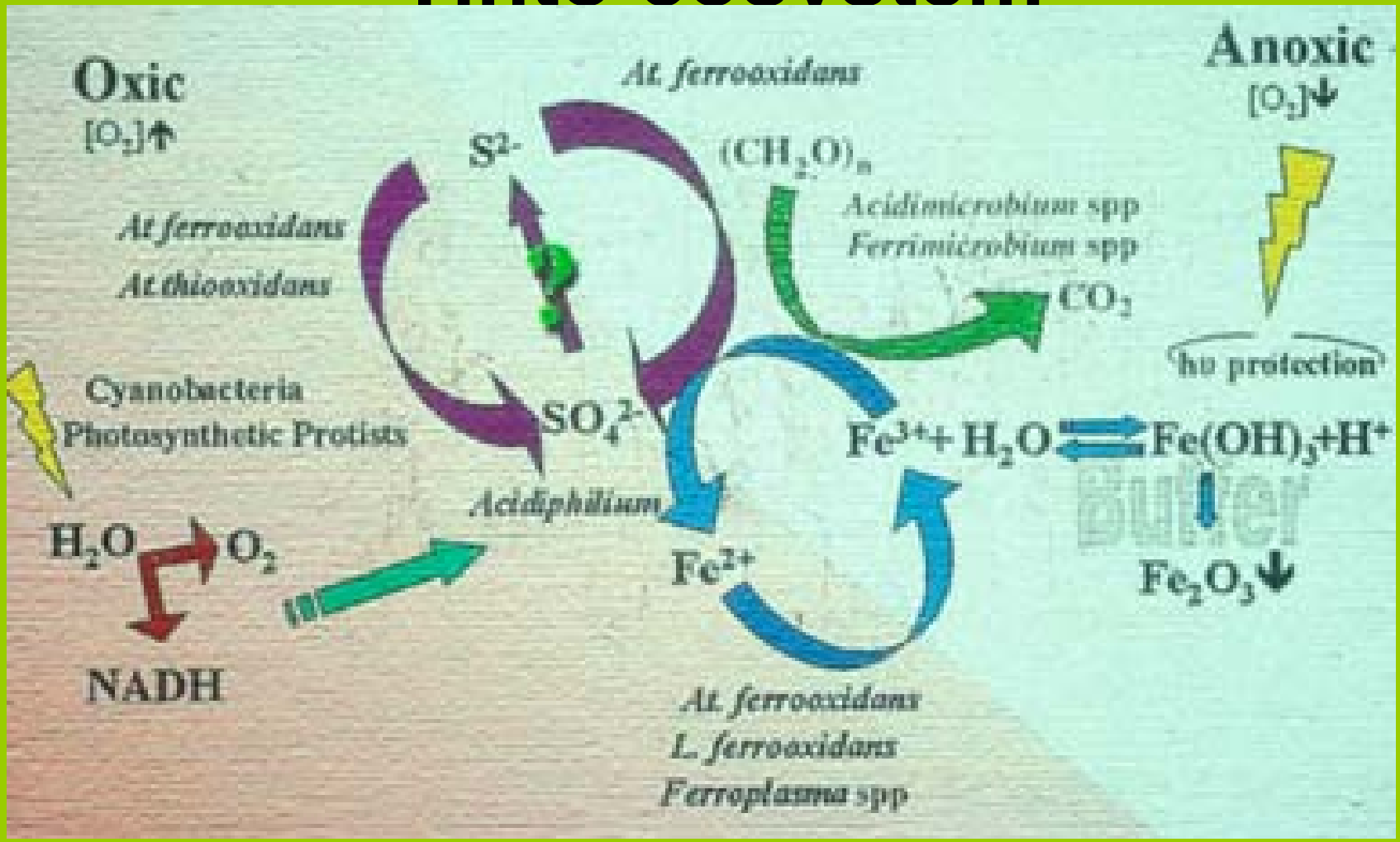
molecular ecology techniques


Archaea
Bacteria
Cya./Chlor.
Euk.
1 4 5 9
1 4 5 9
1 4 5 9
1 4
DGGE
A1
A2
A3
A5
A6
B13
B14
B15
B16
B17
B18
B19
B20
B21
B1
B4
B5
B6
B7
B8
B9
C1
C2
C3
C4
C5
E1
E2
E3
E4
E5
E6

fluorescence in situ hibridación



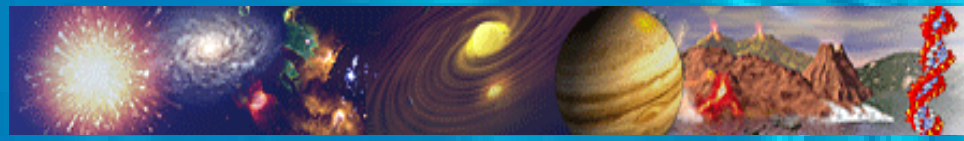
geomicrobiological model of the Tinto cosystem



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



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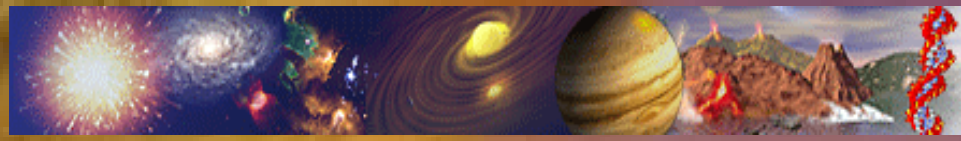
acidophilic diatoms

acidophilic Protists

Dematteaceous fungi

iron bioformations (stromatolites)



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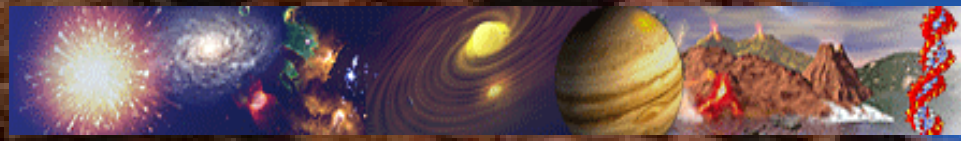
iron stromatolites

fosilization of iron stromatolites



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fosil iron bioformations older than 10^6 years

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MARTE project: geomicrobiological exploration of theTinto subsurface (Pyritic Iberian Belt)

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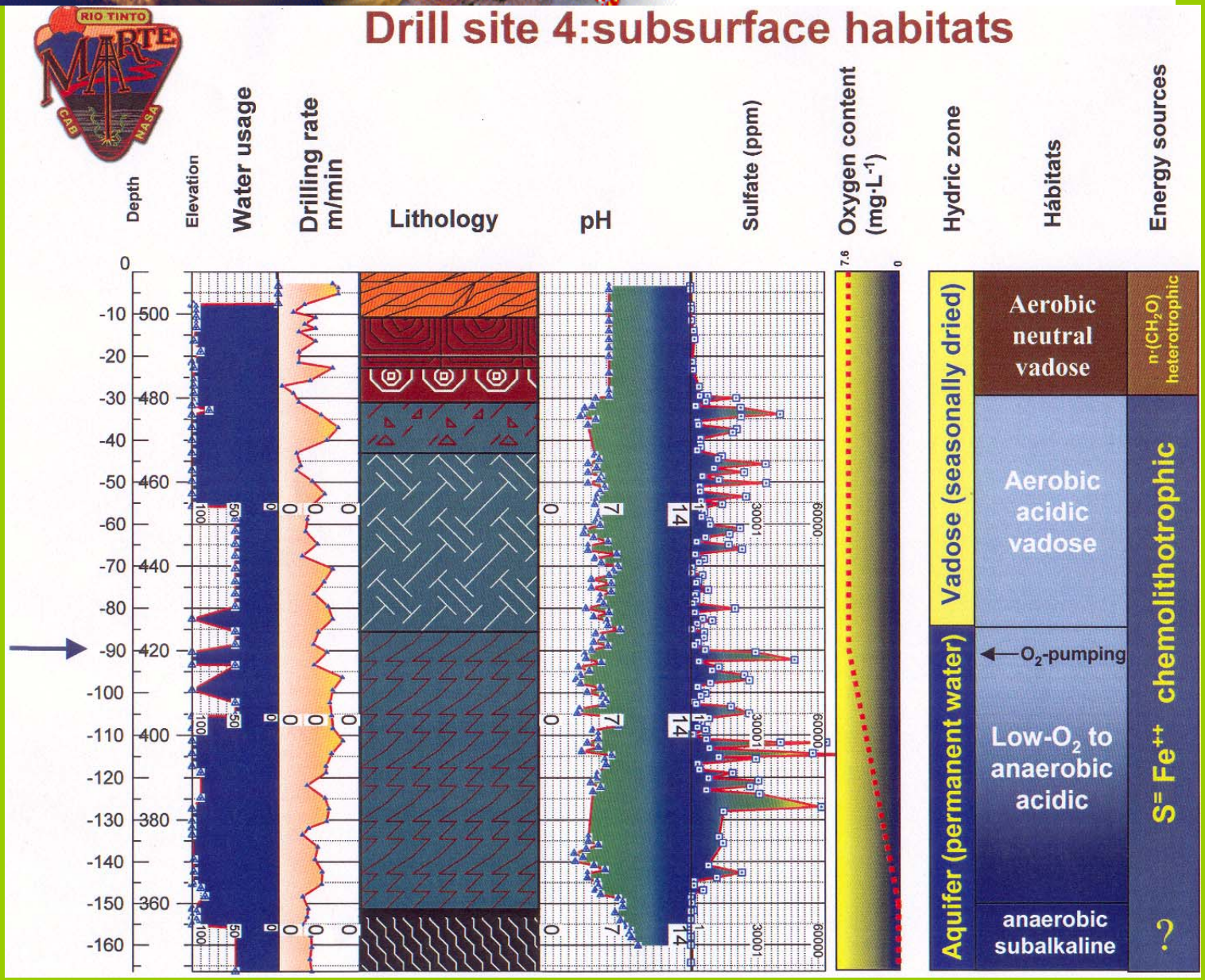
Drill site 4:subsurface habitats



COMPARISON BETWEEN MARS AND THE TINTO SYSTEM

	MP	RTsurf	RTss
- hematite	++	++	+
- jarosite	++	++	+
- goethite	++	++	+
- ionic strength	++	++	++
- temperature surf	low	4-35^{o}C	
- temperature ss	?		10^{o}C
- methane	+/-	-	+
- oxygen	+/-	++	-
- µorganisms	?	++	+

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