Methanogenic activity in Río Tinto, a terrestrial Mars analogue

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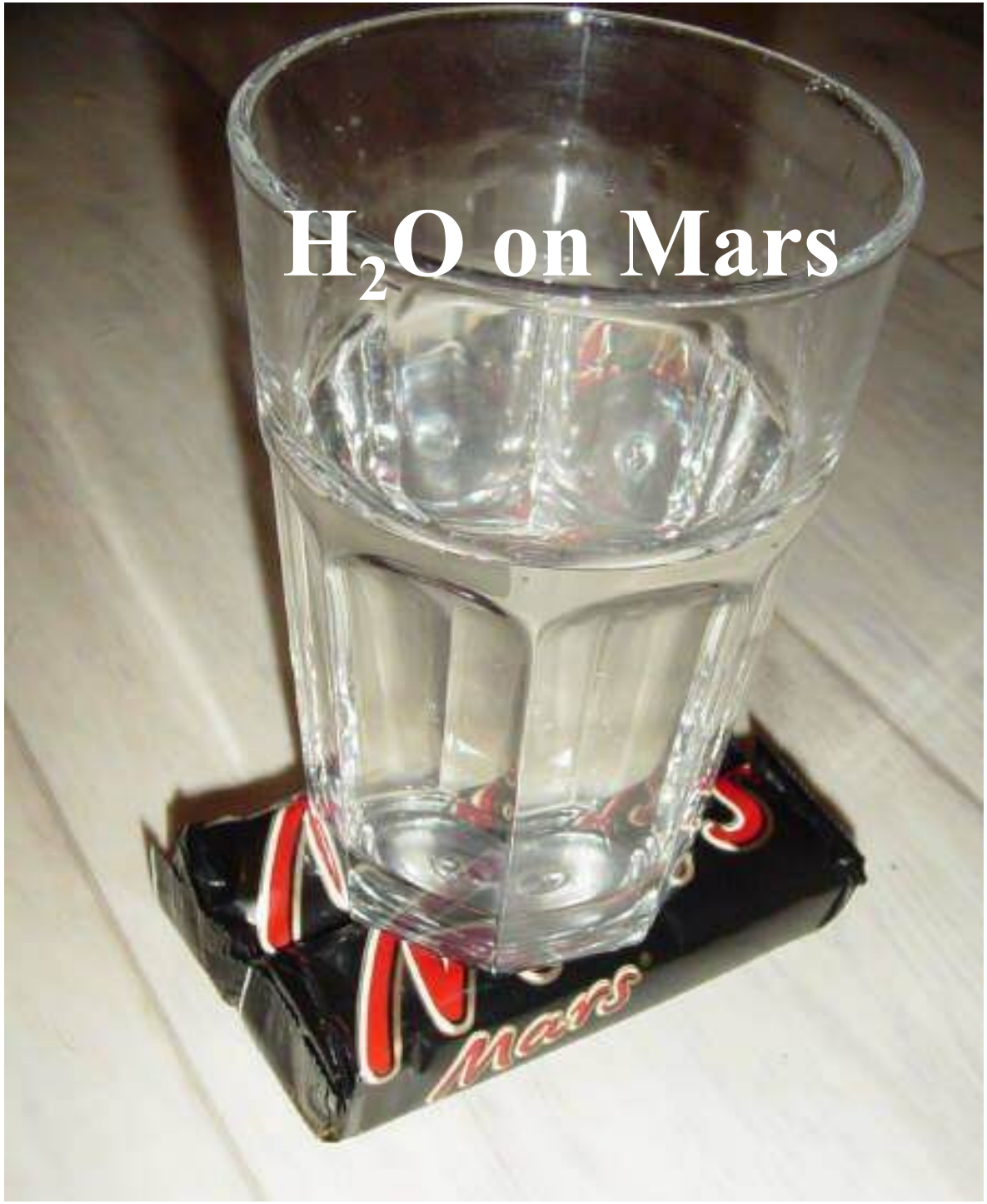
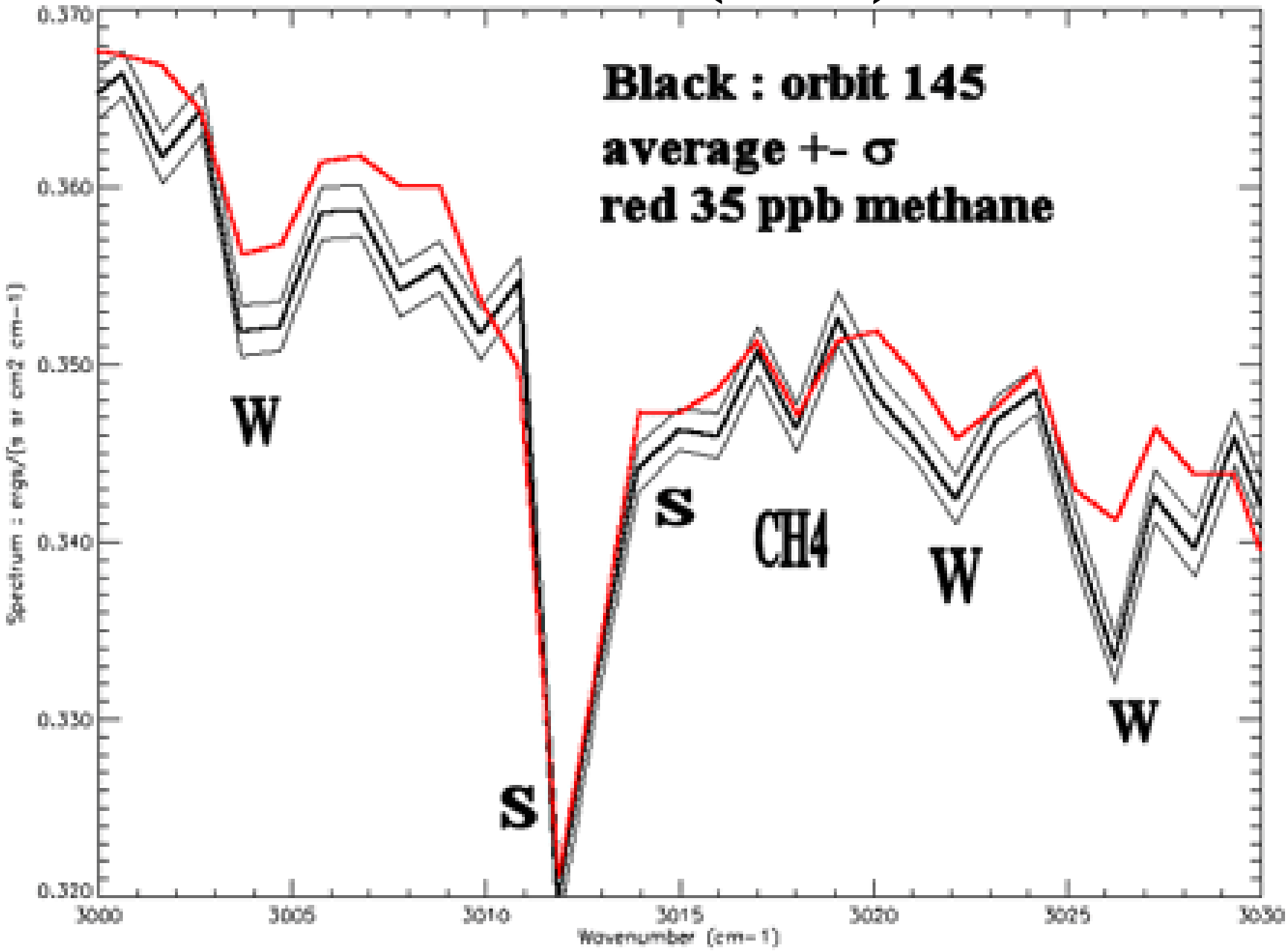
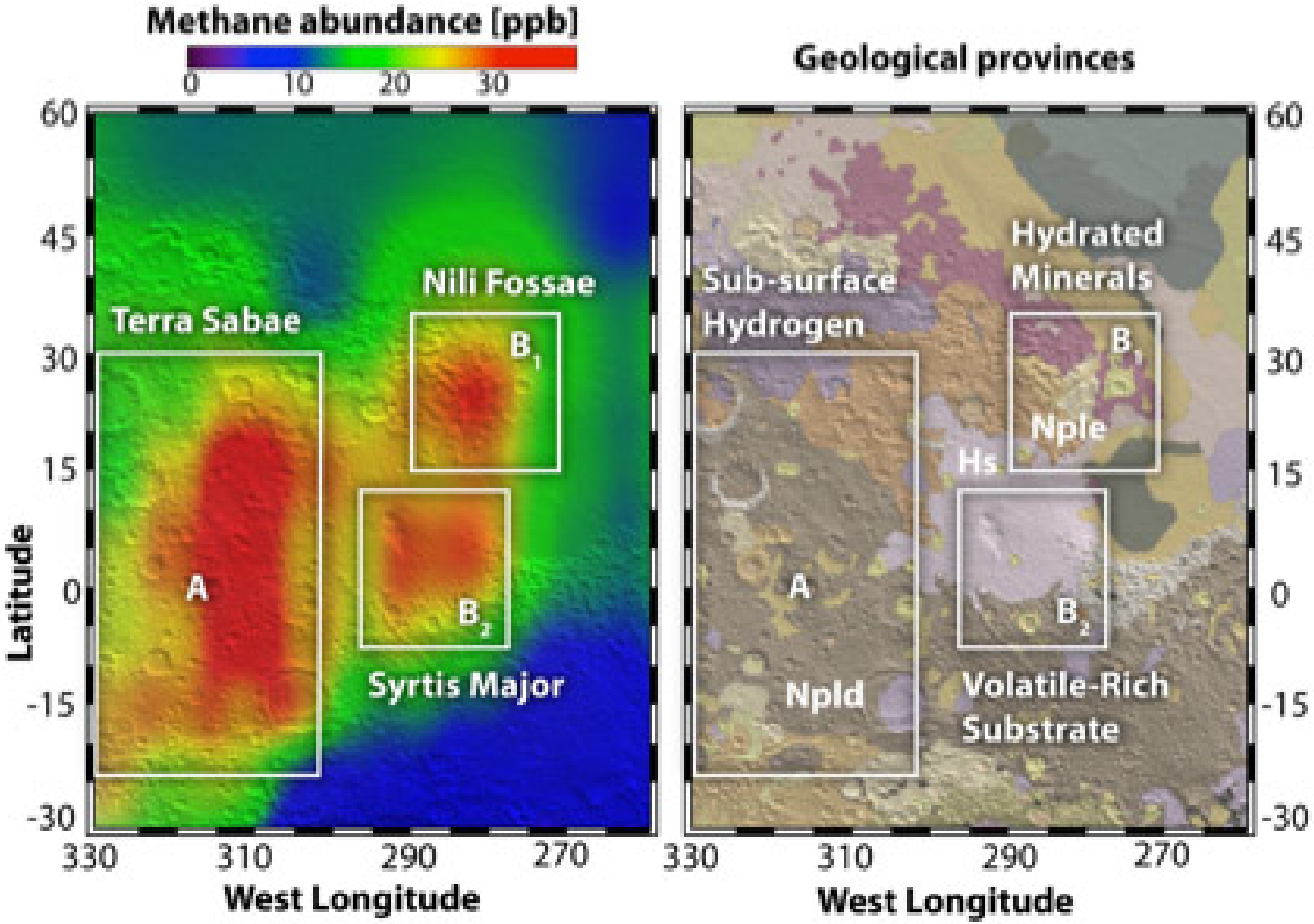
new insides in the Mars exploration


H_2O on Mars
Mars

methane (PFS)

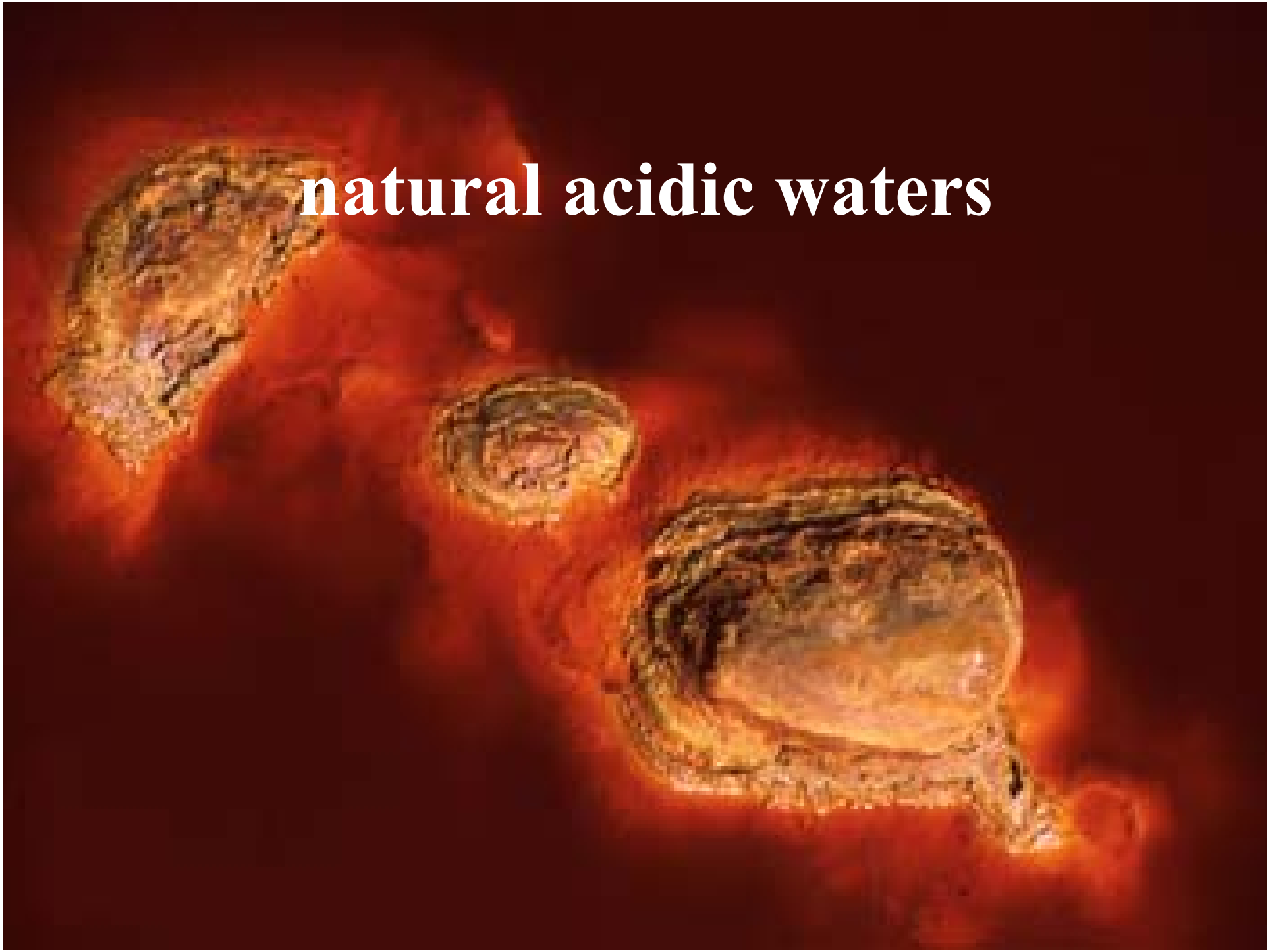

Black : orbit 145
average +- σ
red 35 ppb methane
W
S
S
CH4
W
W
0.370
0.360
0.350
0.340
0.330
0.320
3000
3005
3010
3015
3020
3025
3030
Wavenumber (cm-1)
Spectrum : ergs/(s sr cm2 cm-1)


Methane abundance [ppb]
0
10
20
30
Geological provinces
Terra Sabae
Nili Fossae
Syrtis Major
A
B1
B2
Sub-surface Hydrogen
Hydrated Minerals
Hs
Nple
Npld
Volatile-Rich Substrate
60
45
30
15
0
-15
-30
Latitude
330
310
290
270
West Longitude

it can be concluded that on Mars there are sedimentary rocks that were formed in acidic conditions (acidic lakes or oceans)

- **possible terrestrial analogs:**
  - **submarine hydrothermalism**
  - **acidic environments**


to explore the deep sea requires
expensive equipment (Alvin)


natural acidic waters

natural acidic environments:

- **areas with volcanic activity**

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

- **metal mining activities**

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

in this case the extreme acidic conditions are promoted by biological activity

geomicrobiology of metallic sulfides

pyrite, molibdenite, tungstenite (thiosulfate mec.)

$$FeS_2 + 6Fe^{3+} + 3H_2O \rightarrow S_2O_3^{2-} + 7Fe^{2+} + 6H^+$$

$$S_2O_3^{2-} + 8Fe^{3+} + 5H_2O \rightarrow 2SO_4^{2-} + 8Fe^{2+} + 10H^+$$

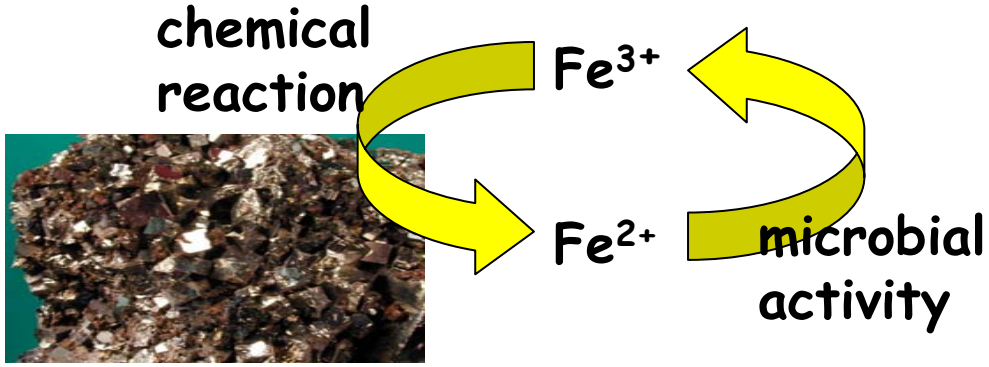
Rest of sulfides (polisulfide mec.)

$$8MS + 8Fe^{3+} + 8H^+ \rightarrow 8M^{2+} + 4H_2S_n + 8Fe^{2+} \quad (n \geq 2)$$

$$4H_2S_n + 8Fe^{3+} \rightarrow S_8^o + 8Fe^{2+} + 8H^+$$

$$S_8^o + 4H_2O \text{ (S oxidizers)} \rightarrow SO_4^{2-} + 8H^+$$

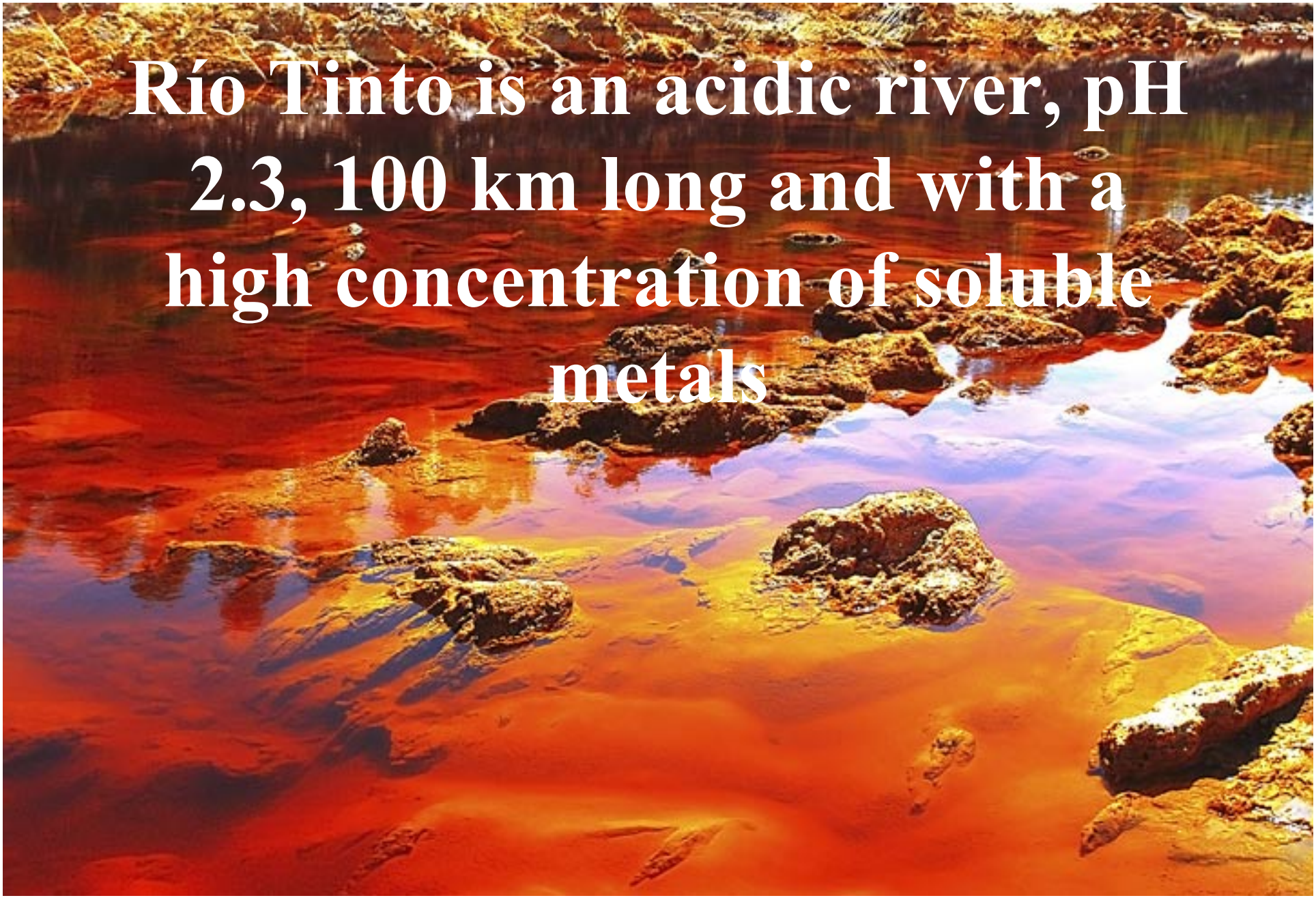
role of the microbial activity in the leaching of pyrite

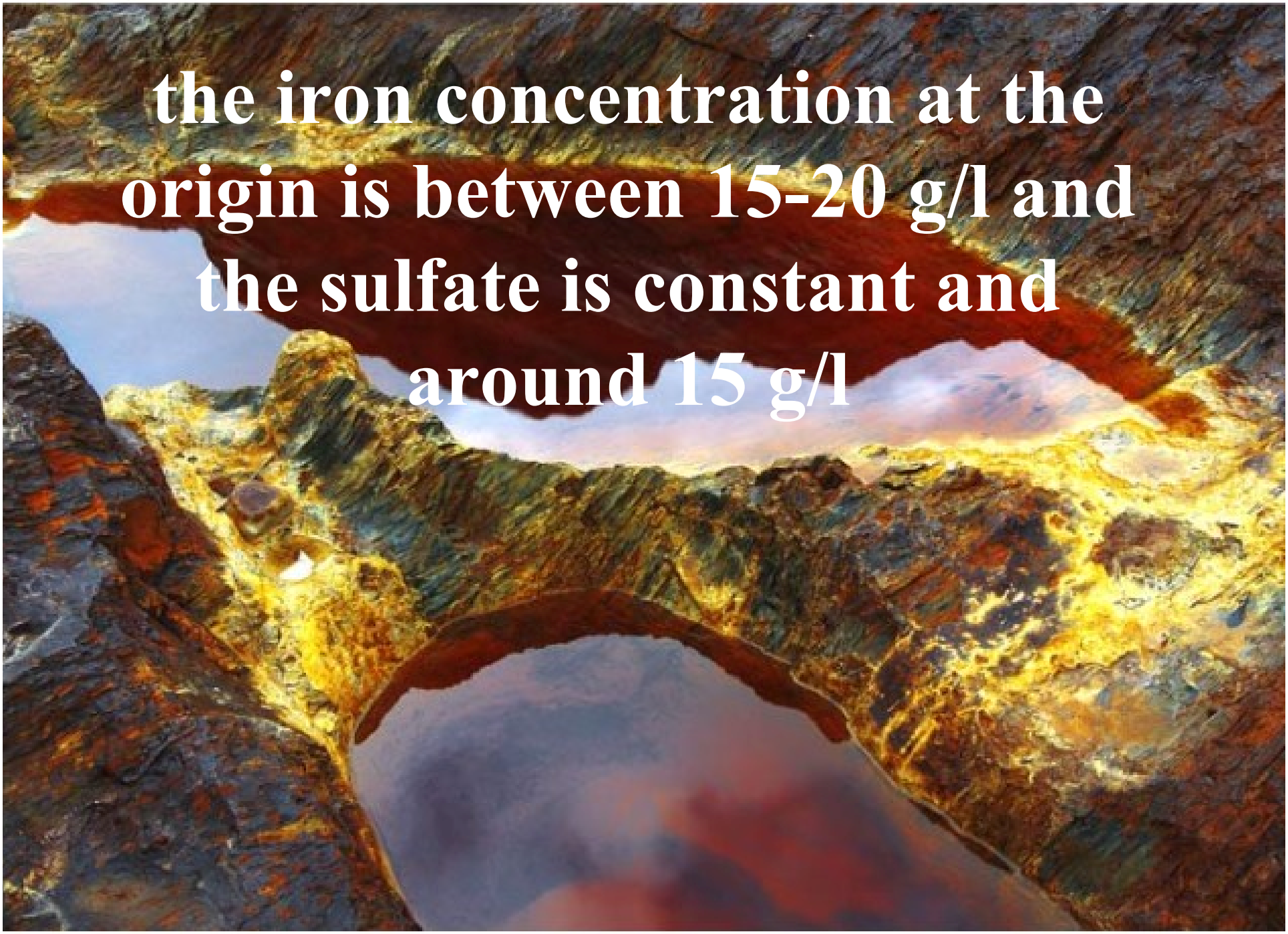


$SO_4^{2-} + H^+$

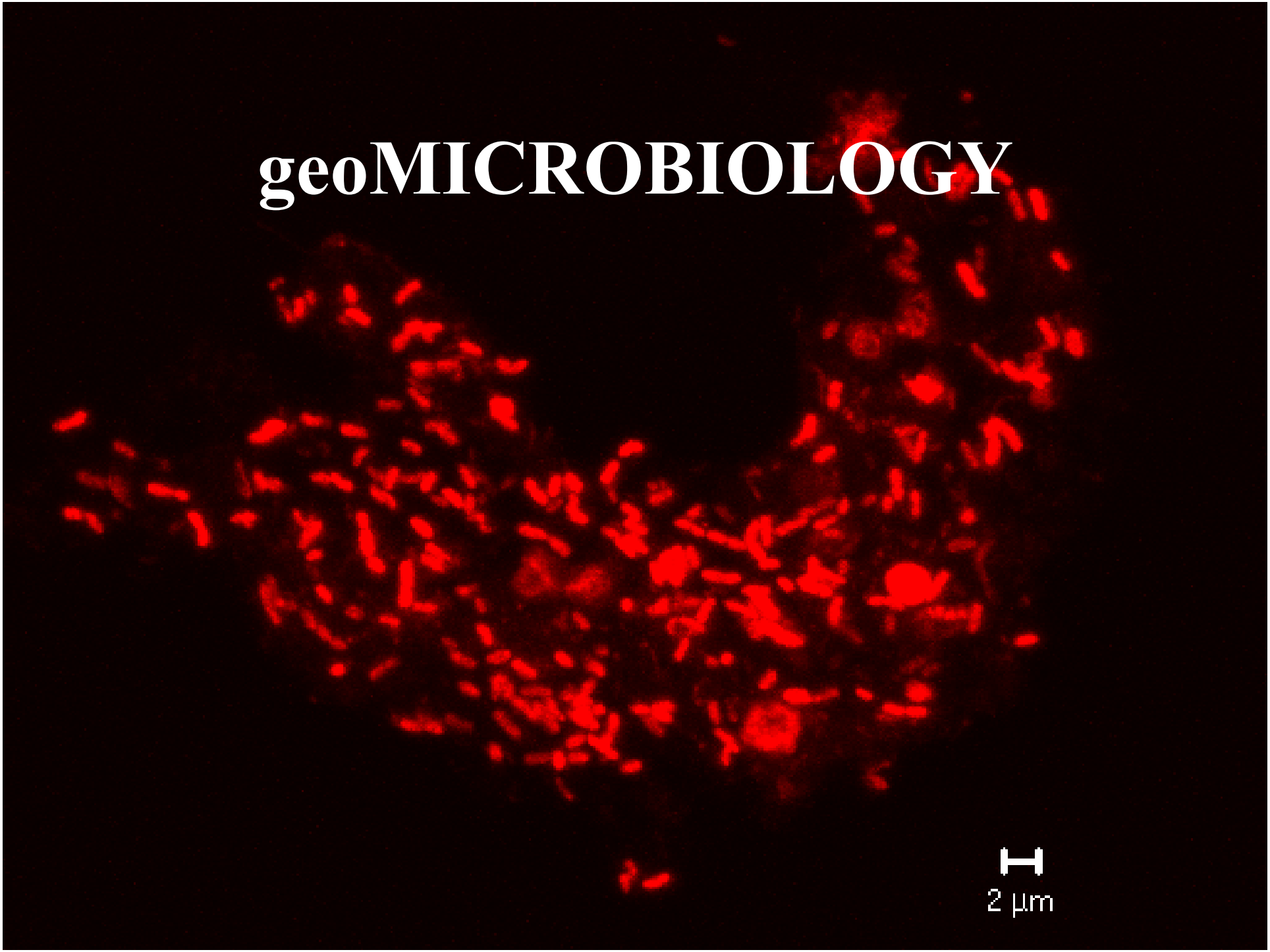

rio Tinto


Rio Tinto rise at the heart of the
Iberian Pyritic Belt

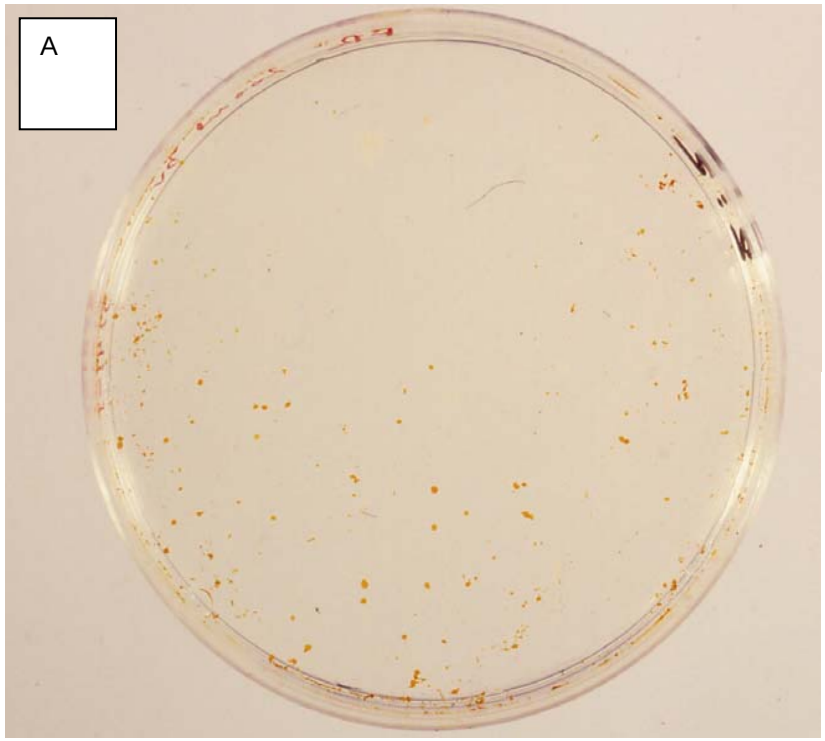

Río Tinto is an acidic river, pH 2.3, 100 km long and with a high concentration of soluble metals

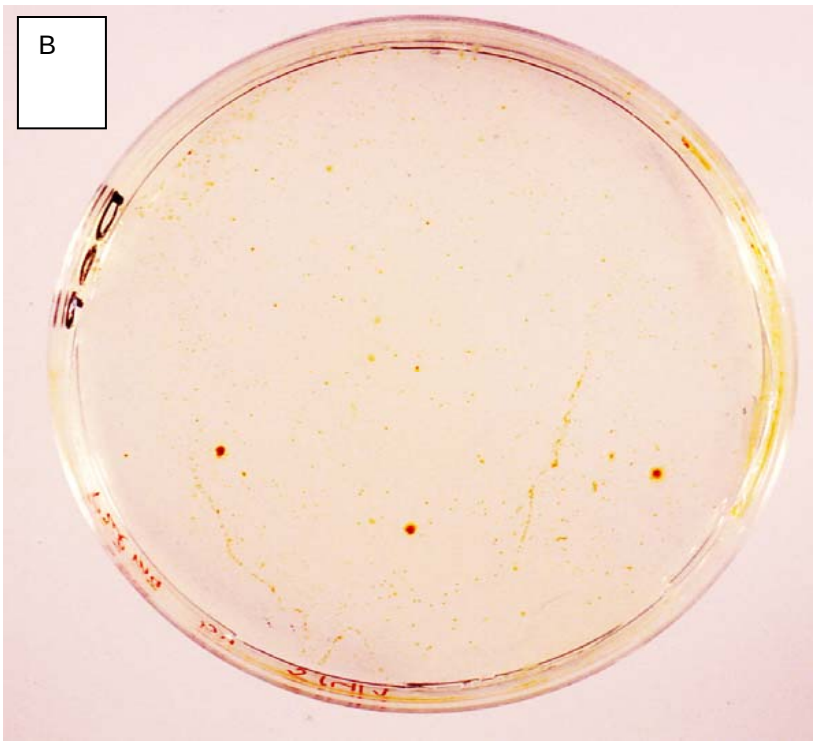

the iron concentration at the origin is between 15-20 g/l and the sulfate is constant and around 15 g/l

geoMICROBIOLOGY



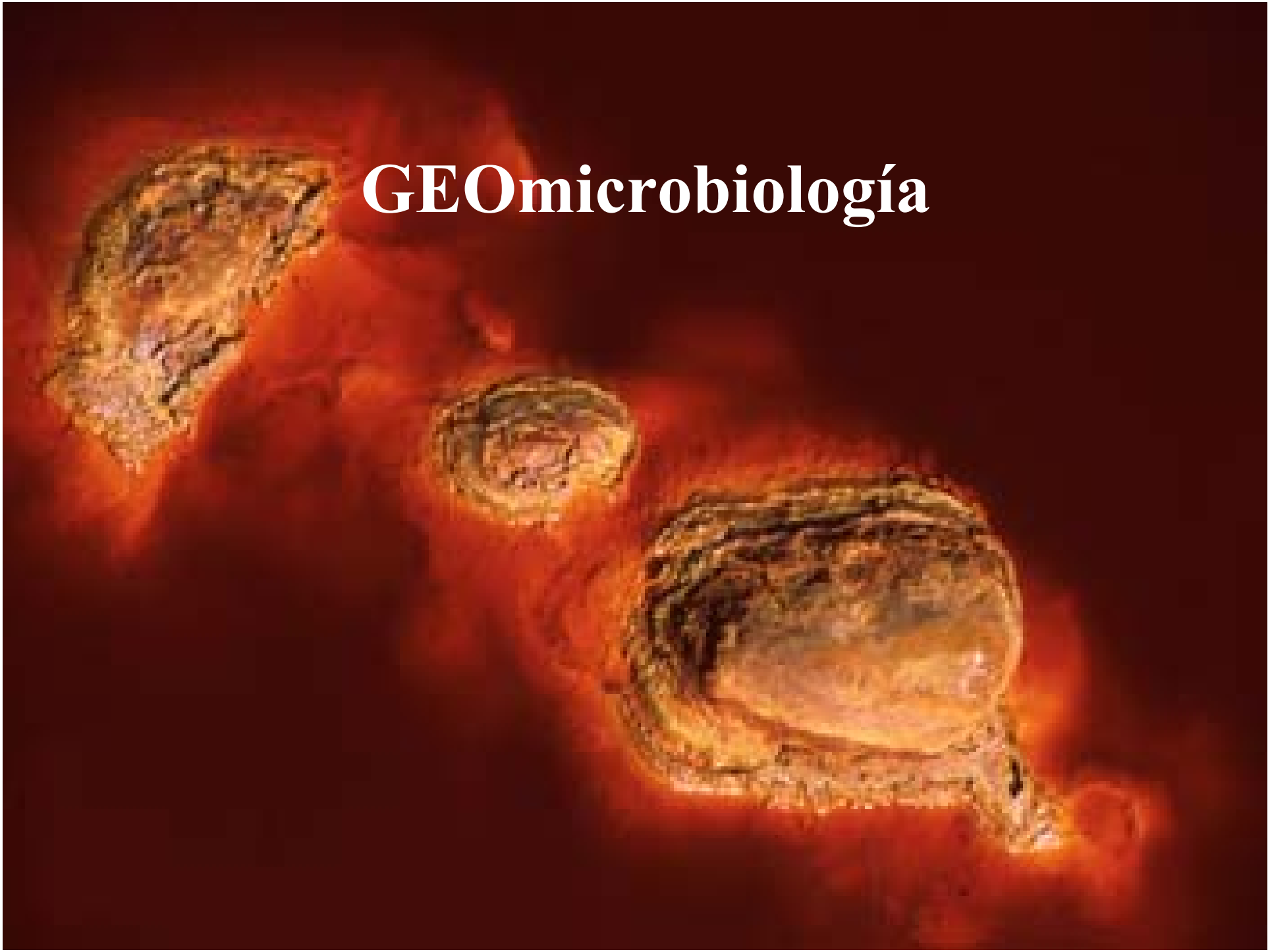
combination of conventional microbial ecology techniques and molecular ecology tools

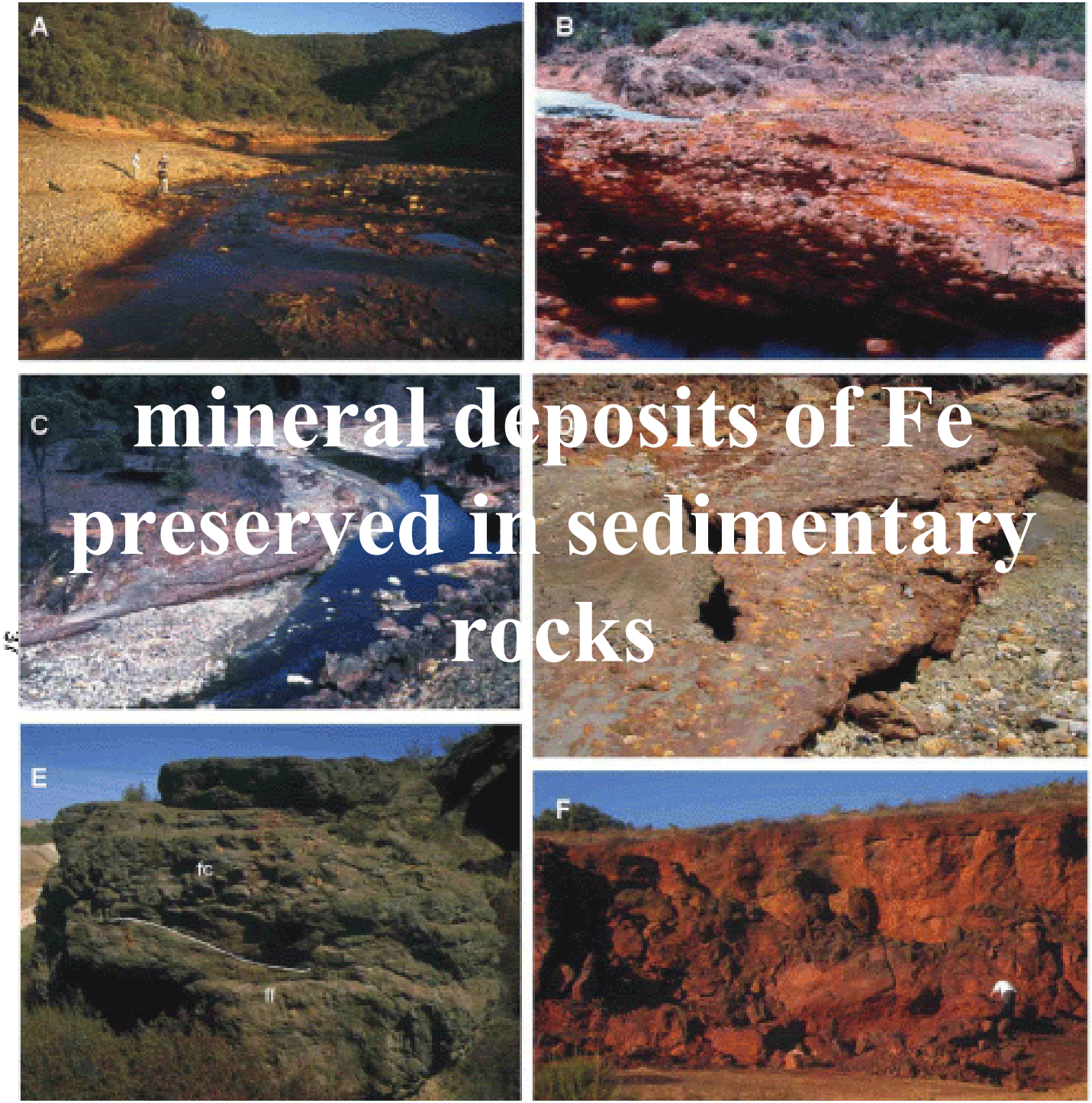




Phylogeny of acidophilic microorganisms detected in Rio Tinto

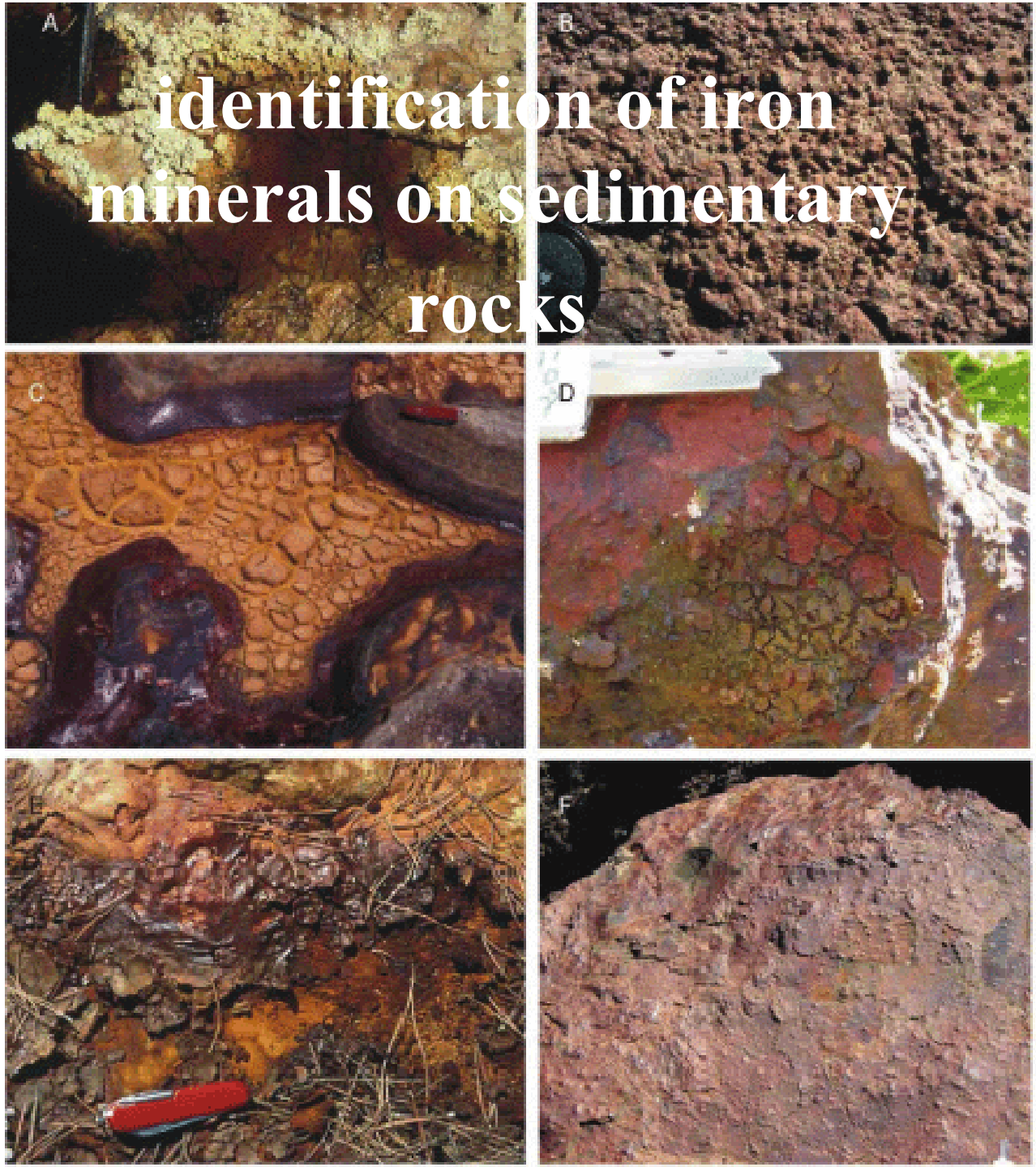
GEOmicrobiología



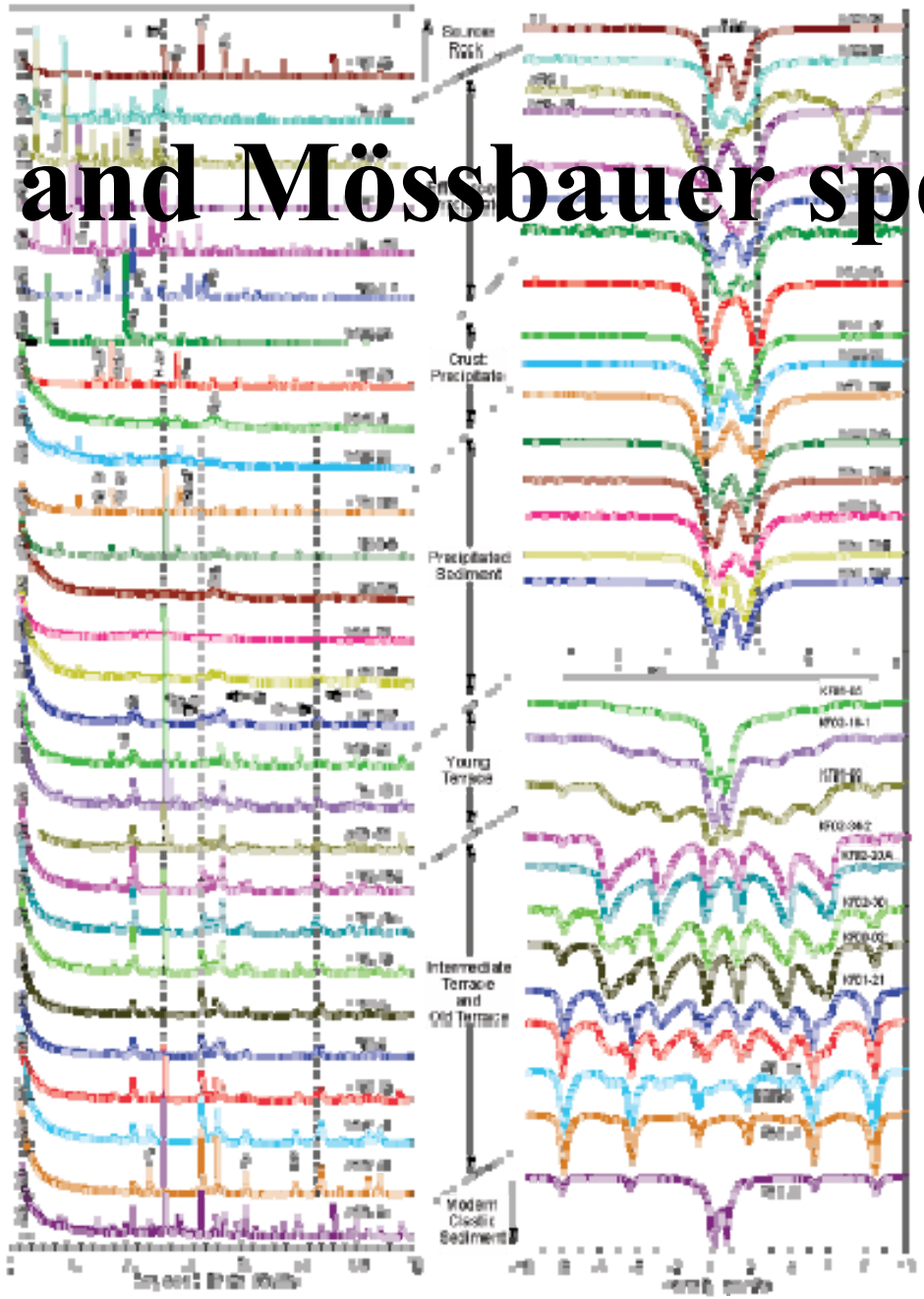


mineral deposits of Fe preserved in sedimentary rocks

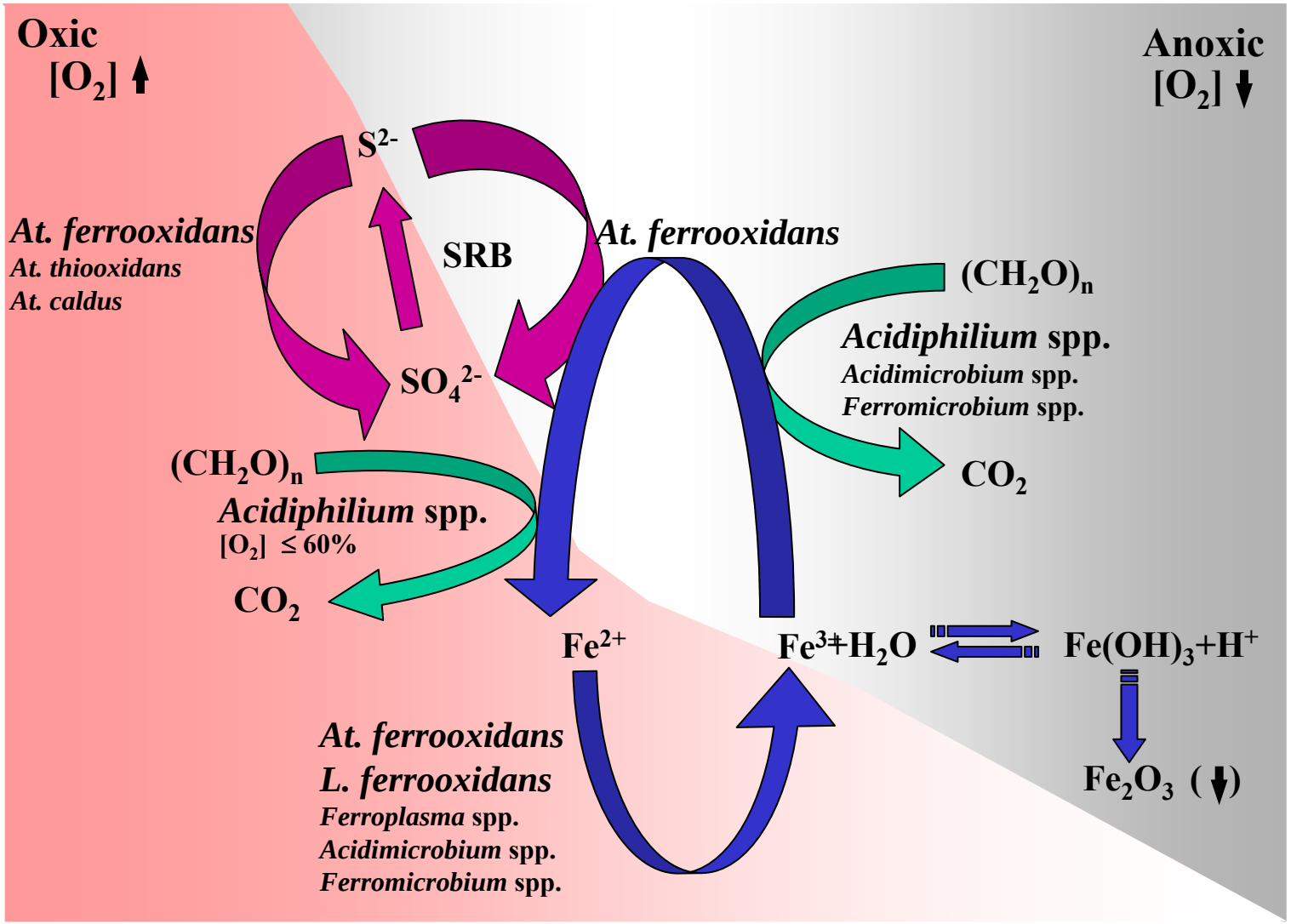
identification of iron minerals on sedimentary rocks

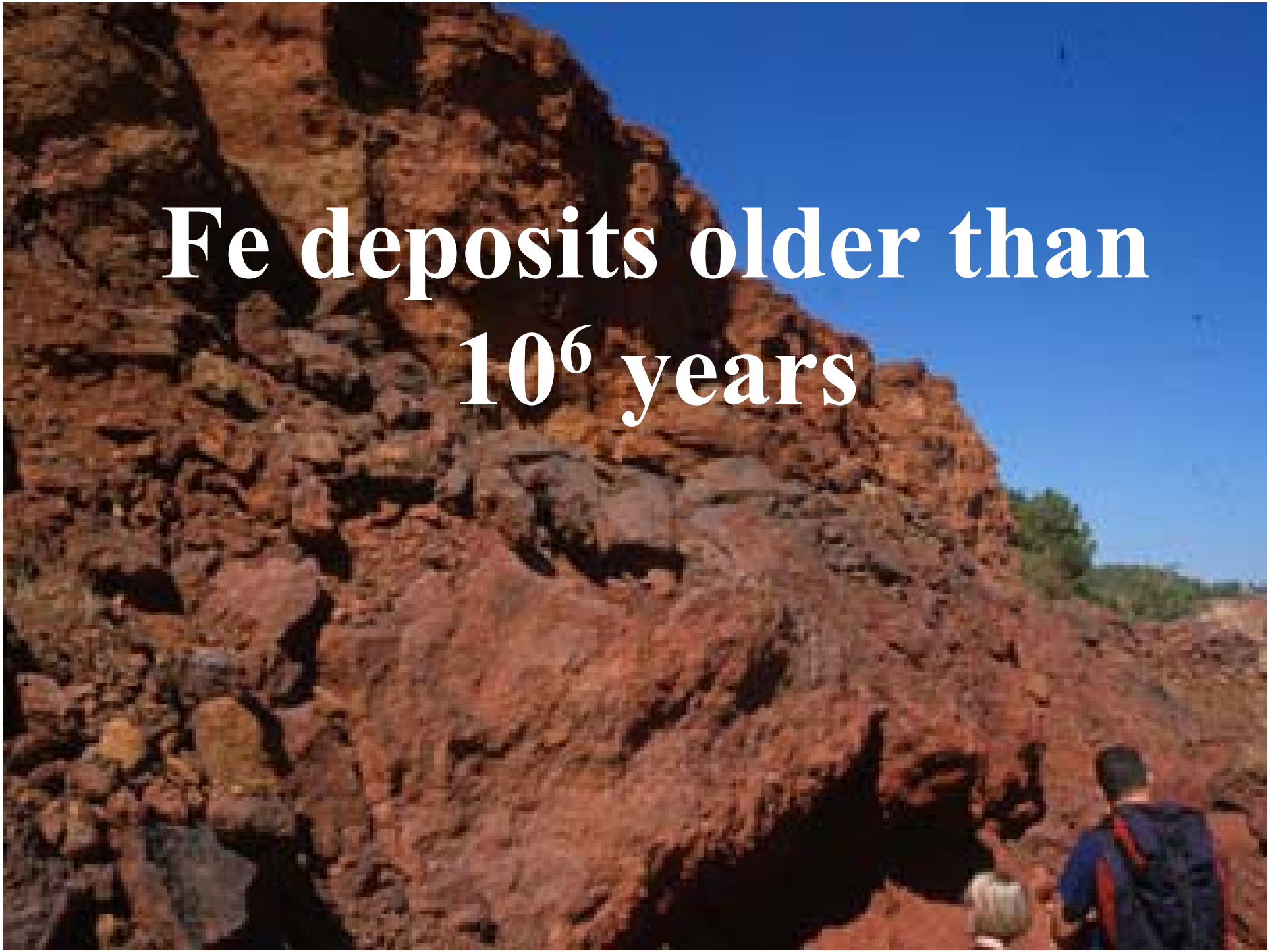


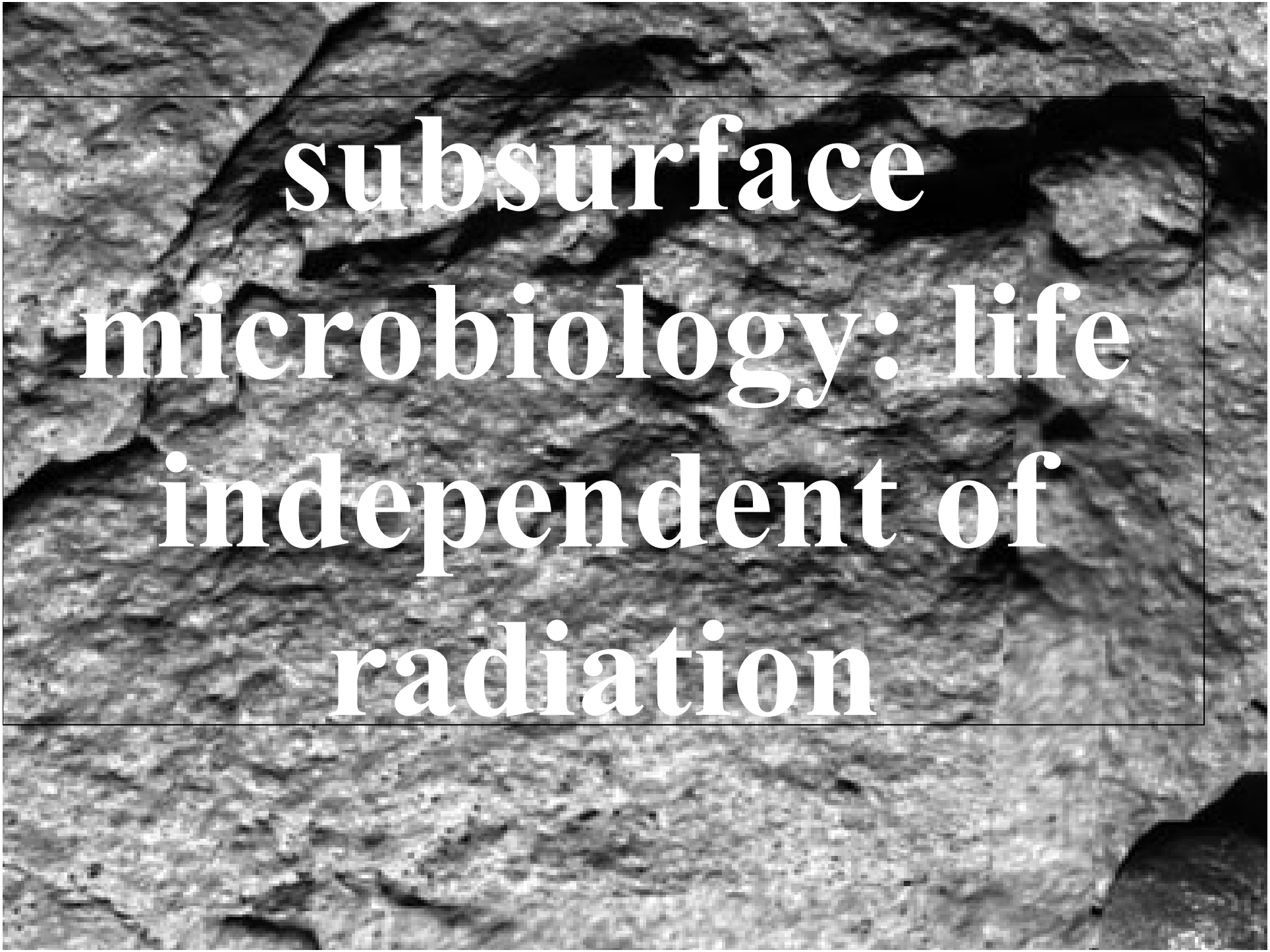
XRD and Mössbauer spectra

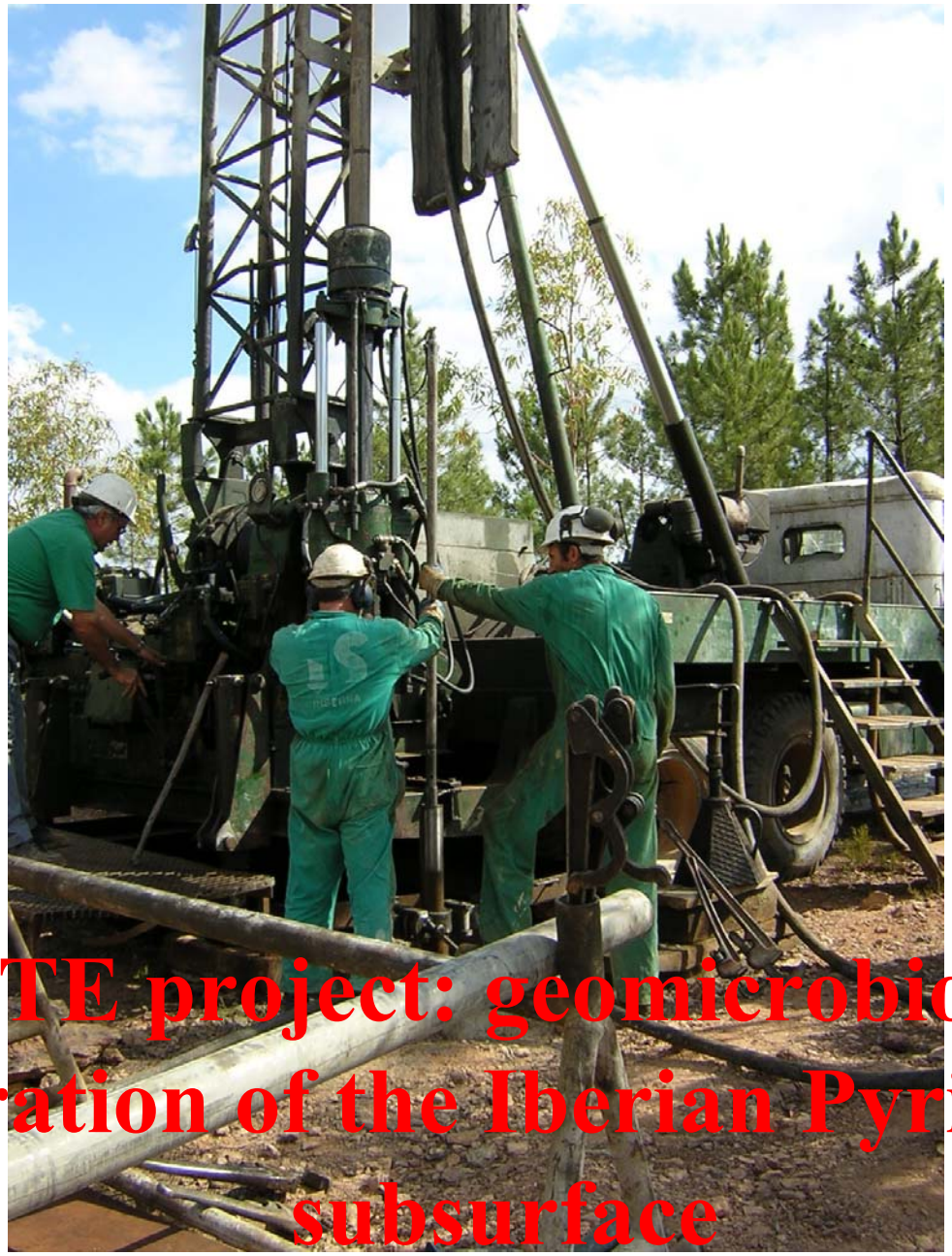


geomicrobiological model of the Río Tinto basin



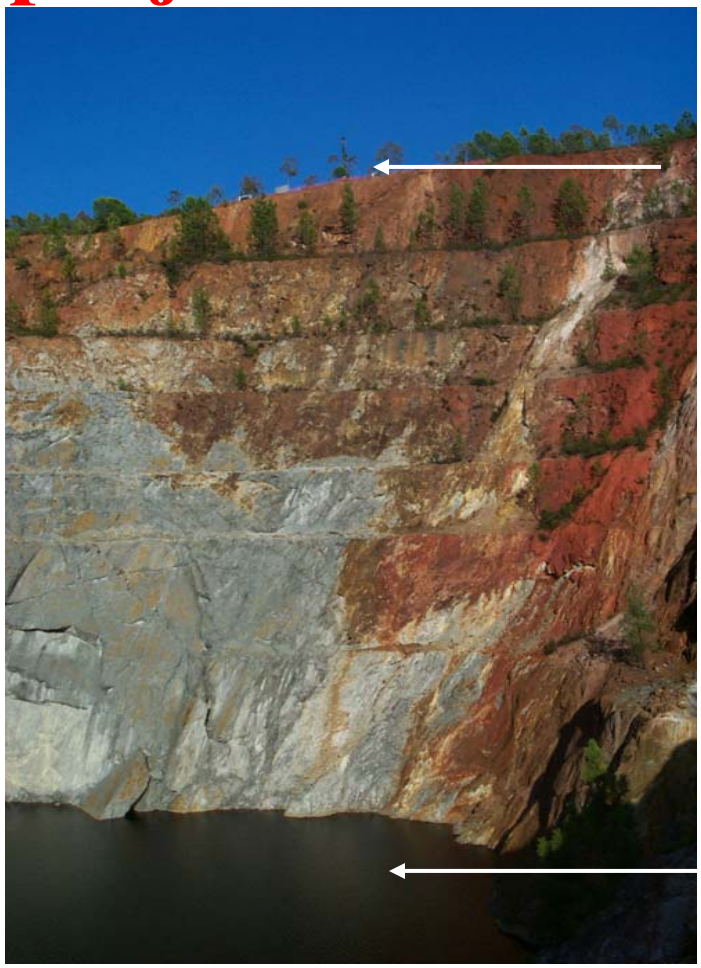

Fe deposits older than
10^6 years


subsurface
microbiology: life
independent of
radiation



MARTE project: geomicrobiological exploration of the Iberian Pyritic Belt subsurface

boreholes drilled during the Marte project.



Geology
Fe and S minerals:
Gossan,
Pyrite,
Hematite,
Goethite,
Sulfates
(Jarosite)

Core Processing Steps

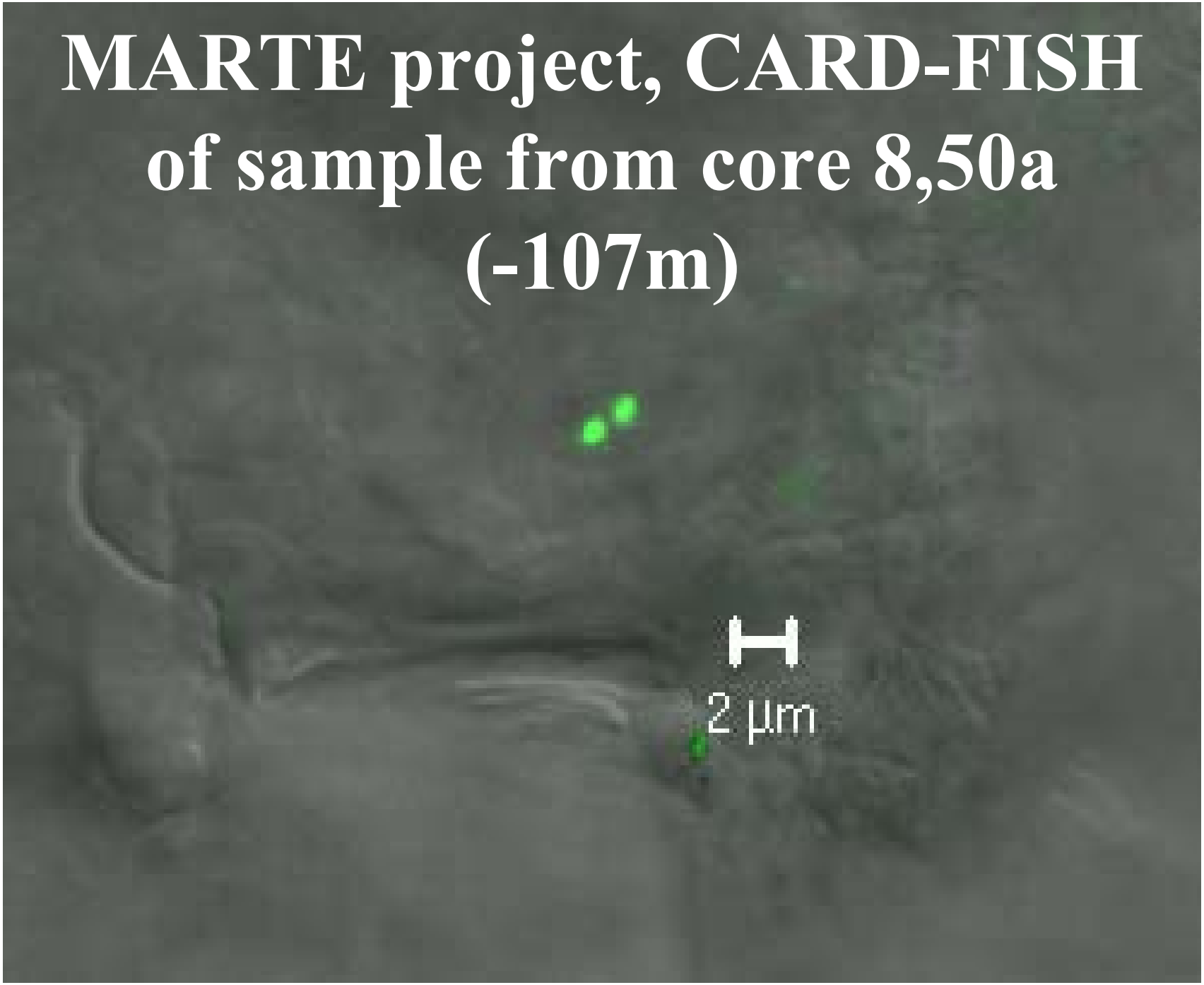
Cores brought to surface

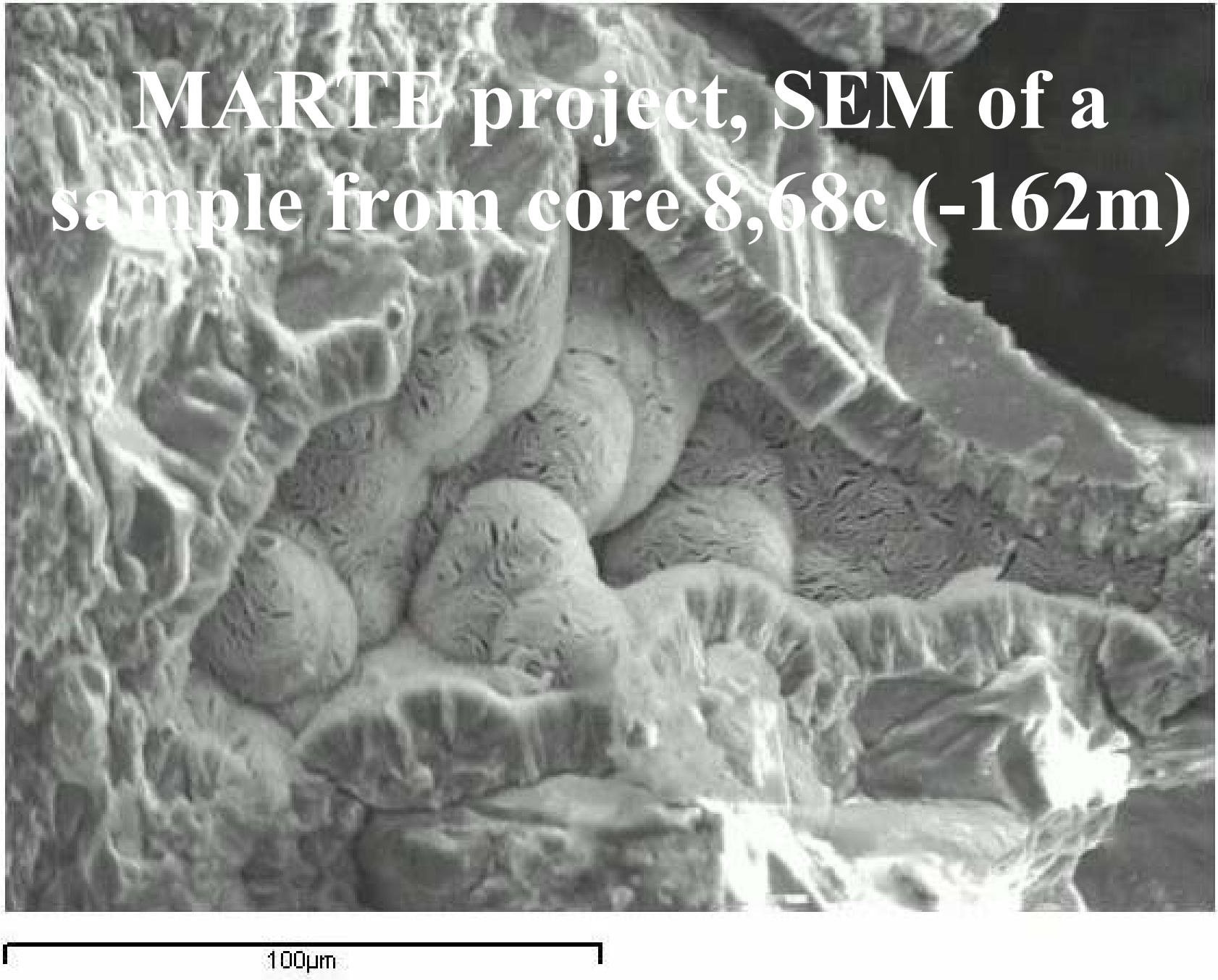
Cores in plastic liners, cut, labeled

Bags filled with N_2

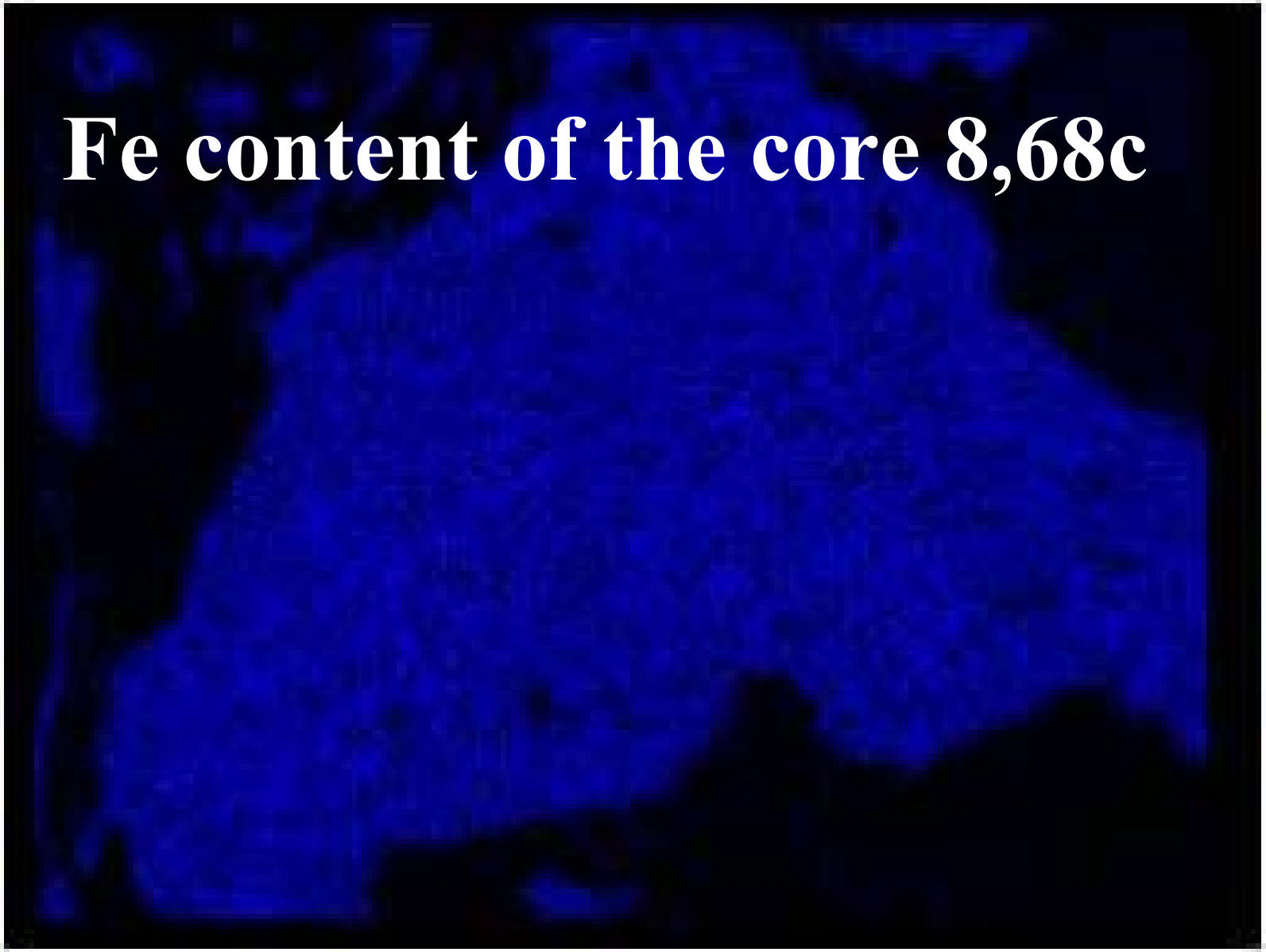
Anaerobic chamber

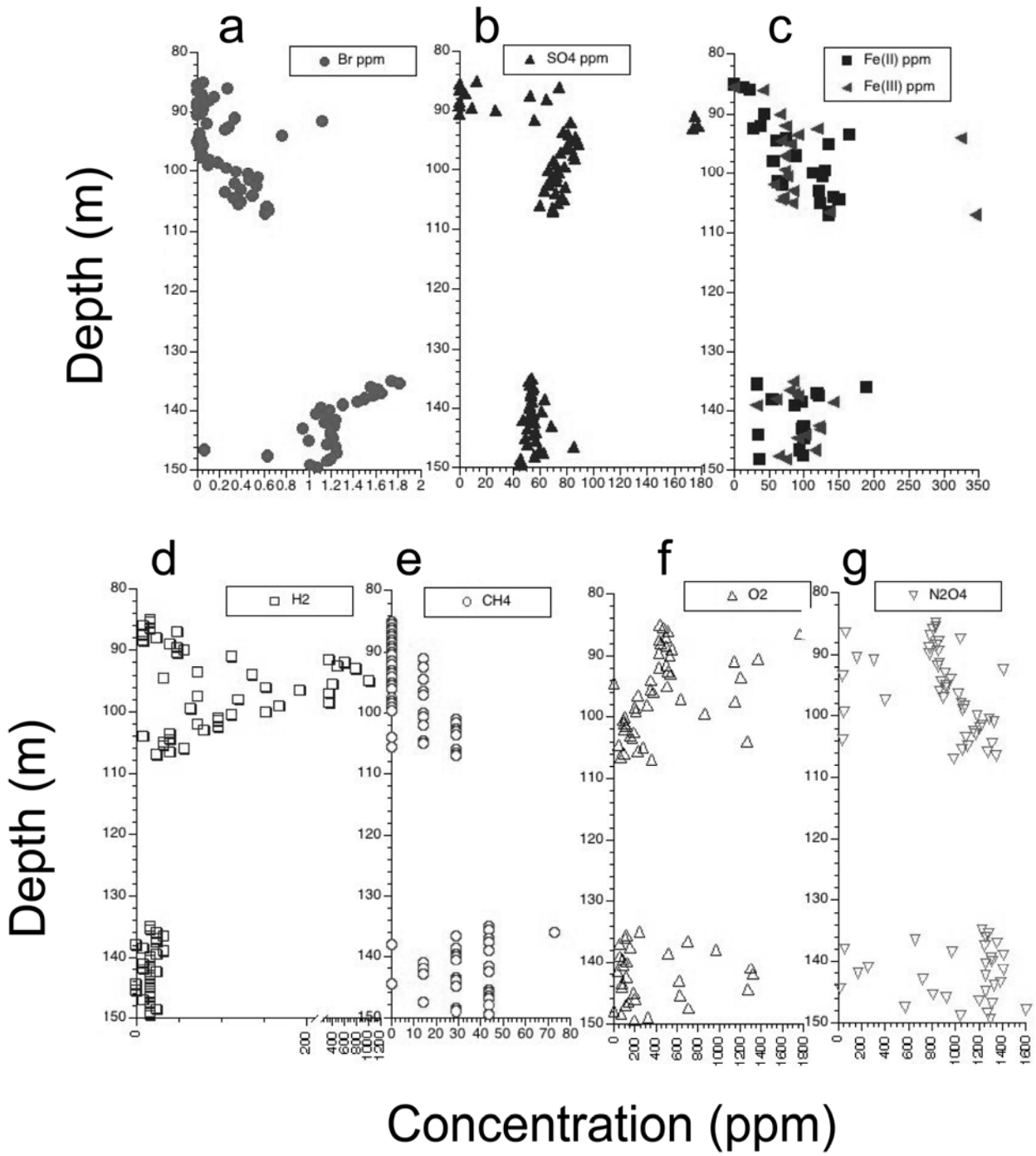
MARTE project, CARD-FISH of sample from core 8,50a (-107m)



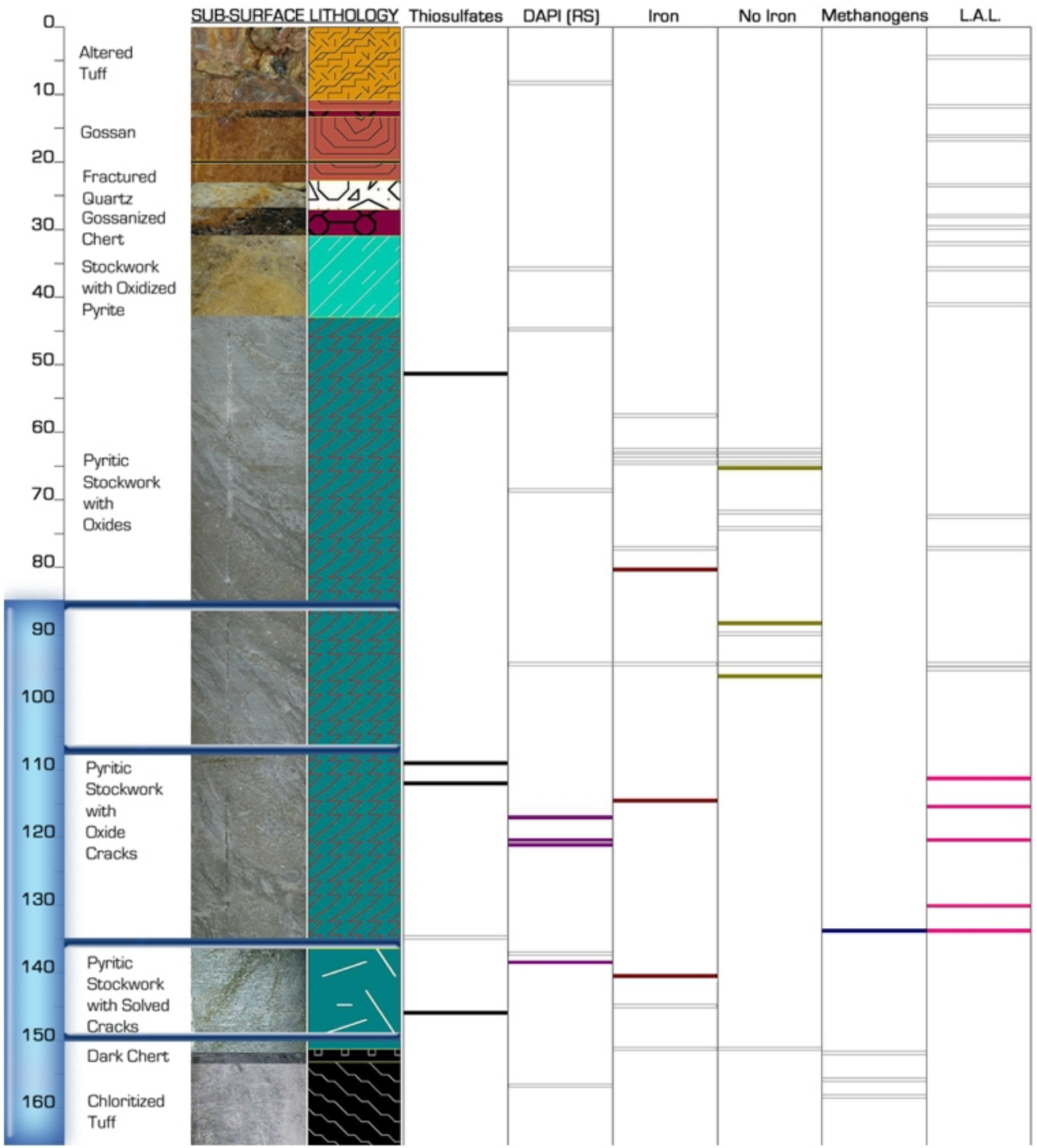

MARTE project, SEM of a sample from core 8,68c (-162m)
100µm

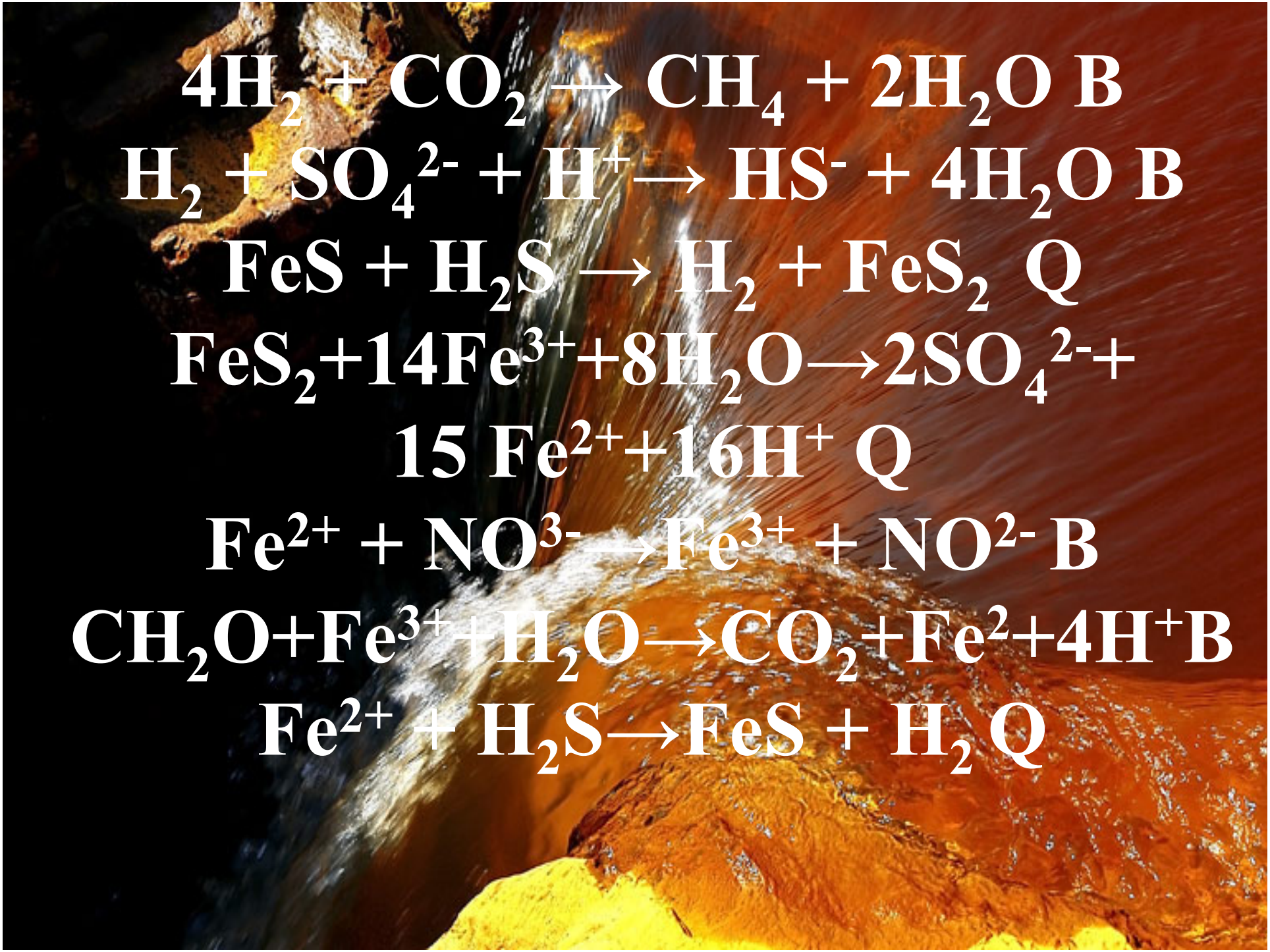
Fe content of the core 8,68c



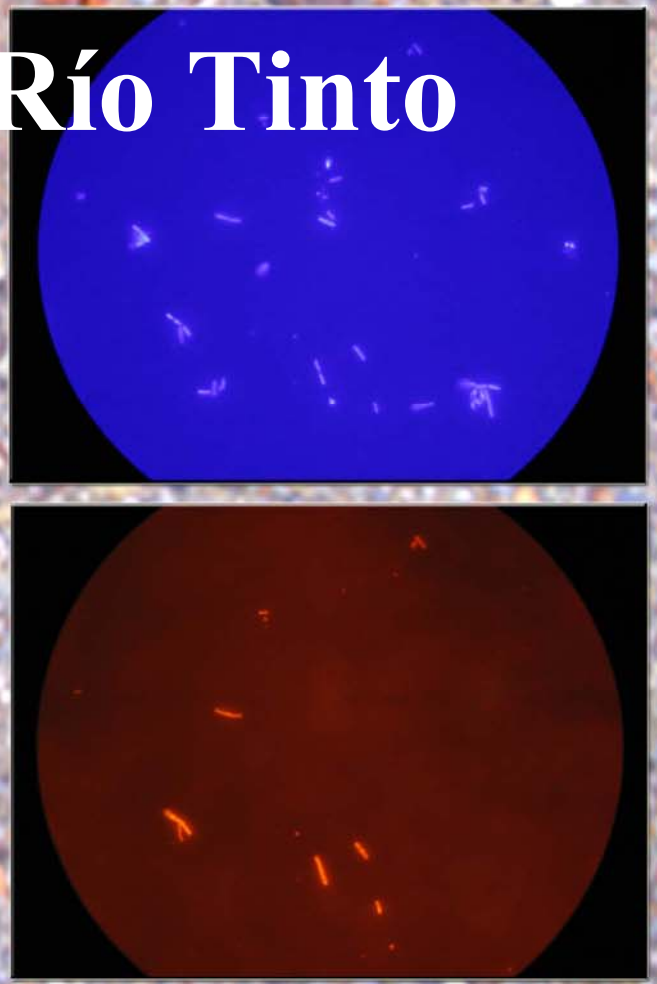

a
Br ppm
b
SO4 ppm
c
Fe(II) ppm
Fe(III) ppm
d
H2
e
CH4
f
O2
g
N2O4
Depth (m)
Depth (m)
Concentration (ppm)

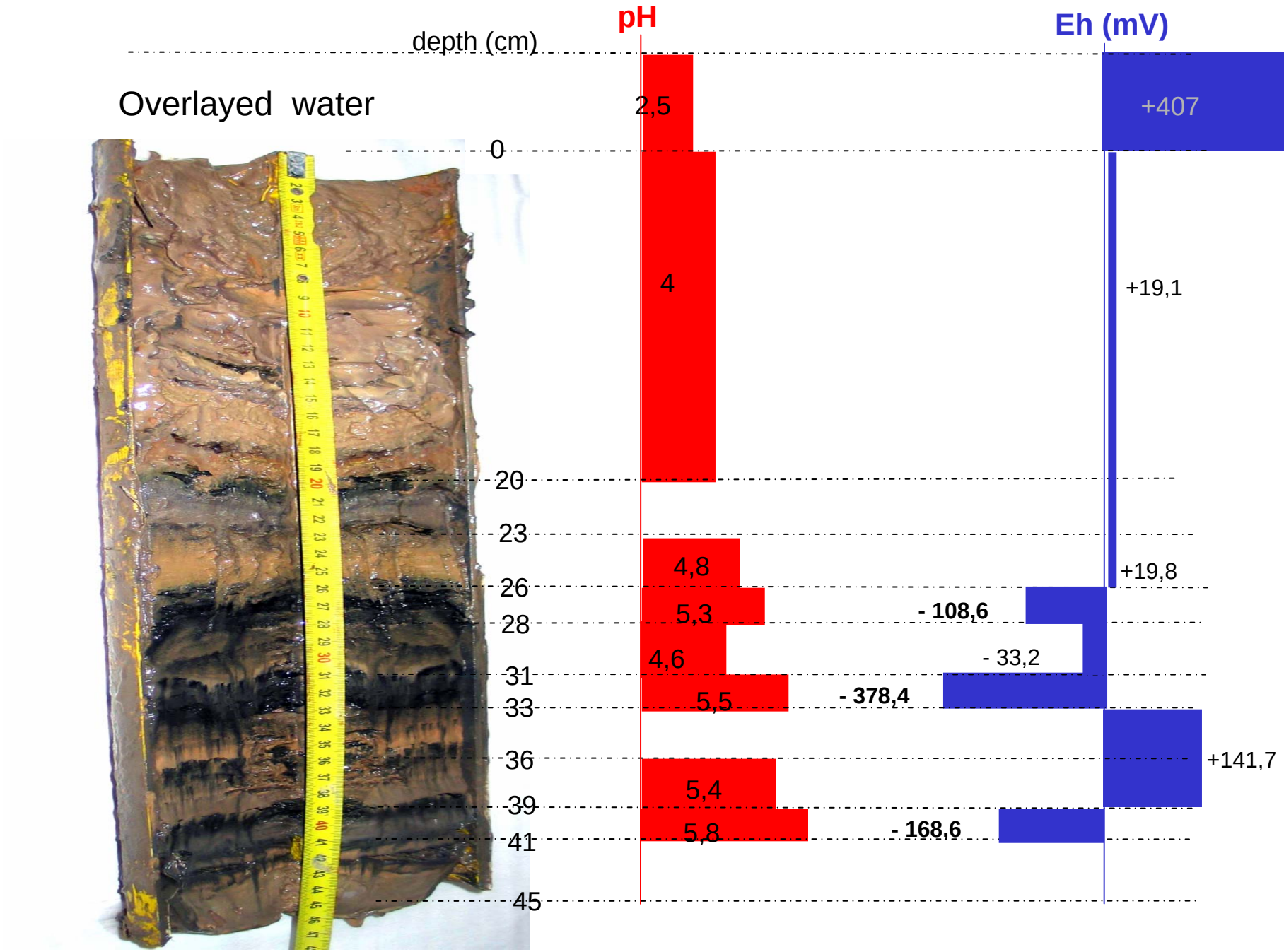

enrichment cultures : Fe and S
oxidizers, SRBs and
methanogens

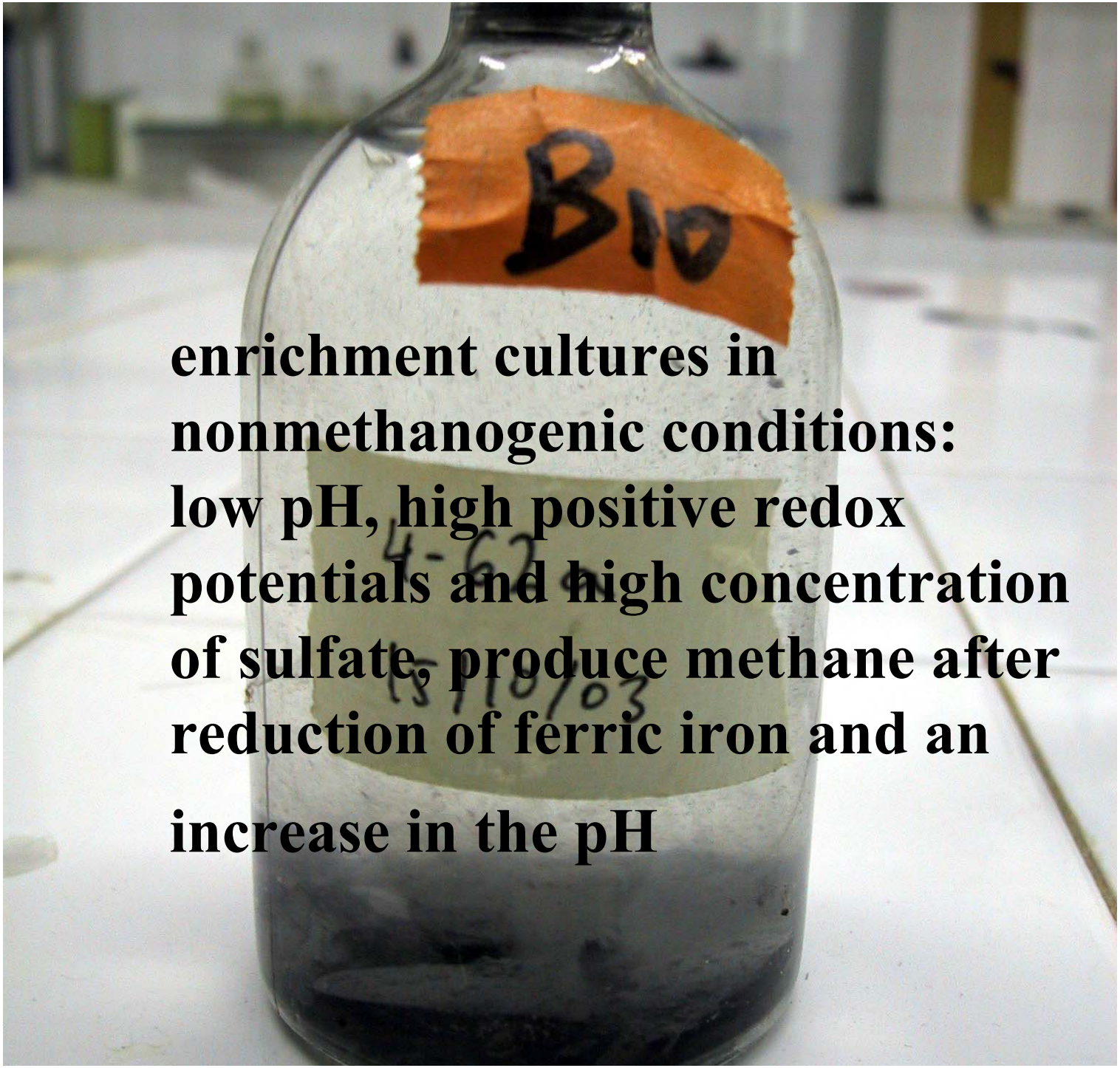

SUB-SURFACE LITHOLOGY
Thiosulfates
DAPI (RS)
Iron
No Iron
Methanogens
L.A.L.
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
Altered Tuff
Gossan
Fractured Quartz Gossanized Chert
Stockwork with Oxidized Pyrite
Pyritic Stockwork with Oxides
Pyritic Stockwork with Oxide Cracks
Pyritic Stockwork with Solved Cracks
Dark Chert
Chloritized Tuff


$4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$ B
$H_2 + SO_4^{2-} + H^+ \rightarrow HS^- + 4H_2O$ B
$FeS + H_2S \rightarrow H_2 + FeS_2$ Q
$FeS_2 + 14Fe^{3+} + 8H_2O \rightarrow 2SO_4^{2-} +$
$15\ Fe^{2+} + 16H^+$ Q
$Fe^{2+} + NO^{3-} \rightarrow Fe^{3+} + NO^{2-}$ B
$CH_2O + Fe^{3+} + H_2O \rightarrow CO_2 + Fe^{2} + 4H^+$ B
$Fe^{2+} + H_2S \rightarrow FeS + H_2$ Q

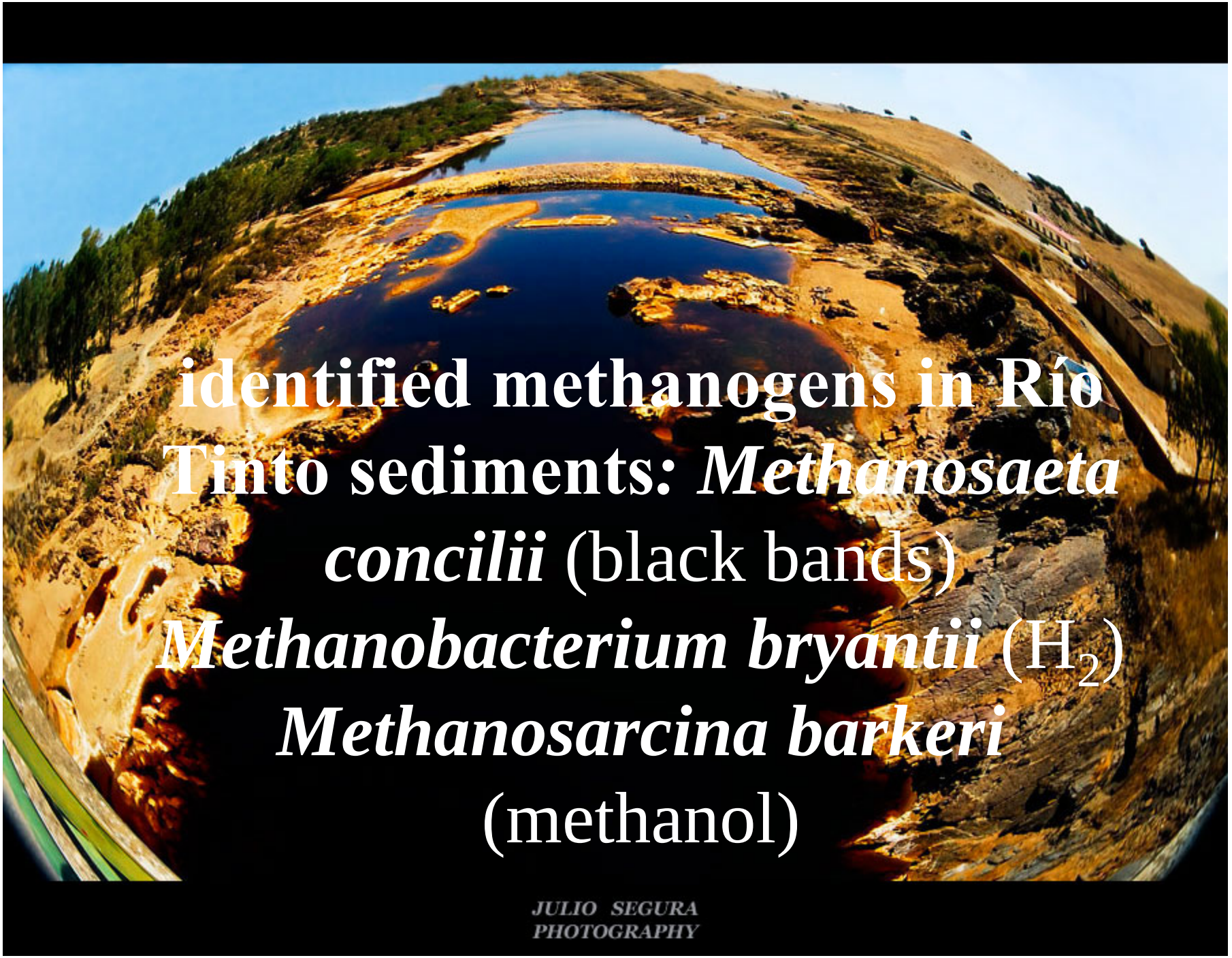
methanogenesis in Río Tinto sediments

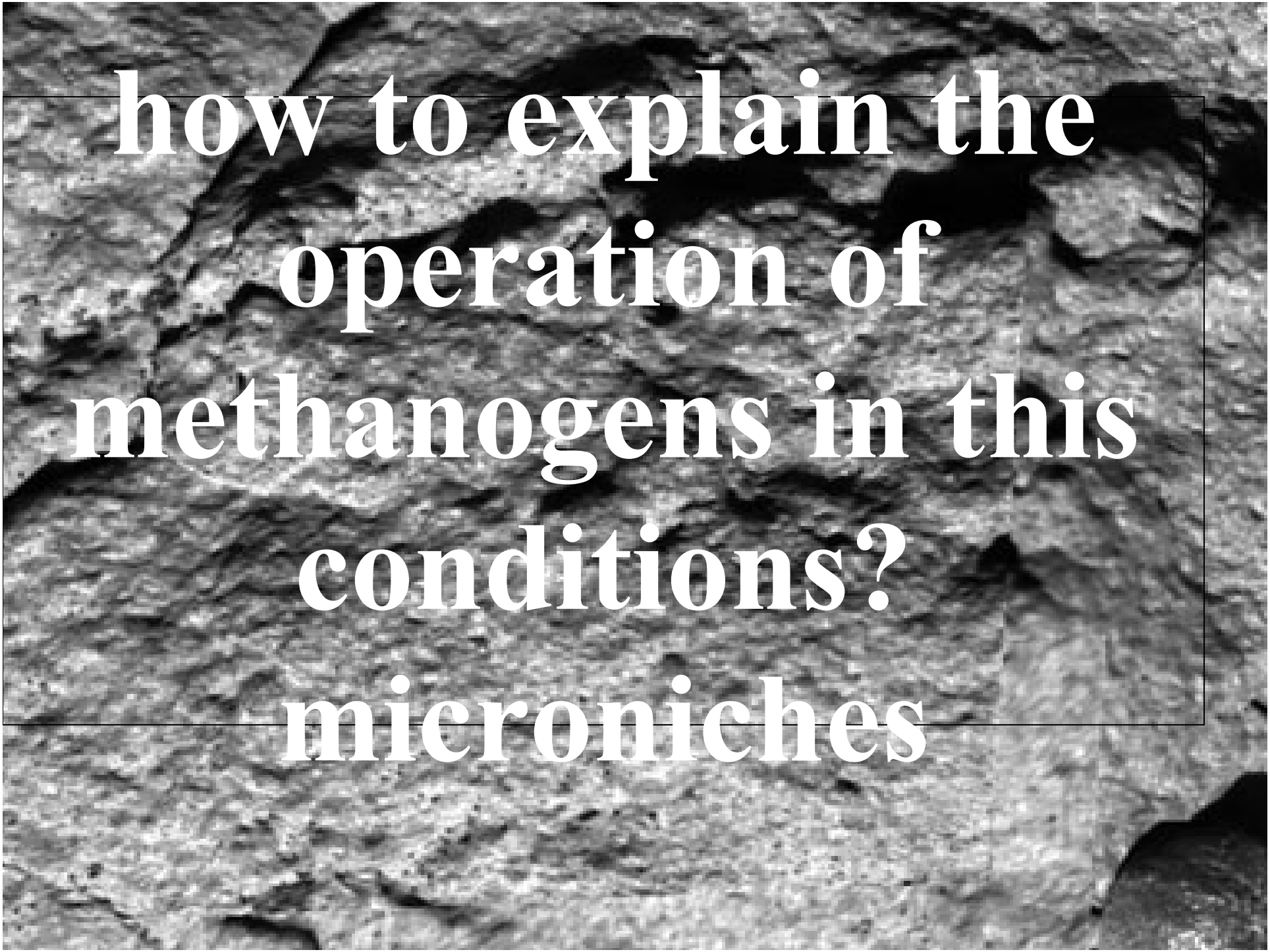



pH
Eh (mV)
depth (cm)
Overlayed water
2,5
+407
0
4
+19,1
20
23
4,8
26
+19,8
5,3
- 108,6
28
4,6
- 33,2
31
5,5
- 378,4
33
36
+141,7
5,4
39
5,8
- 168,6
41
45



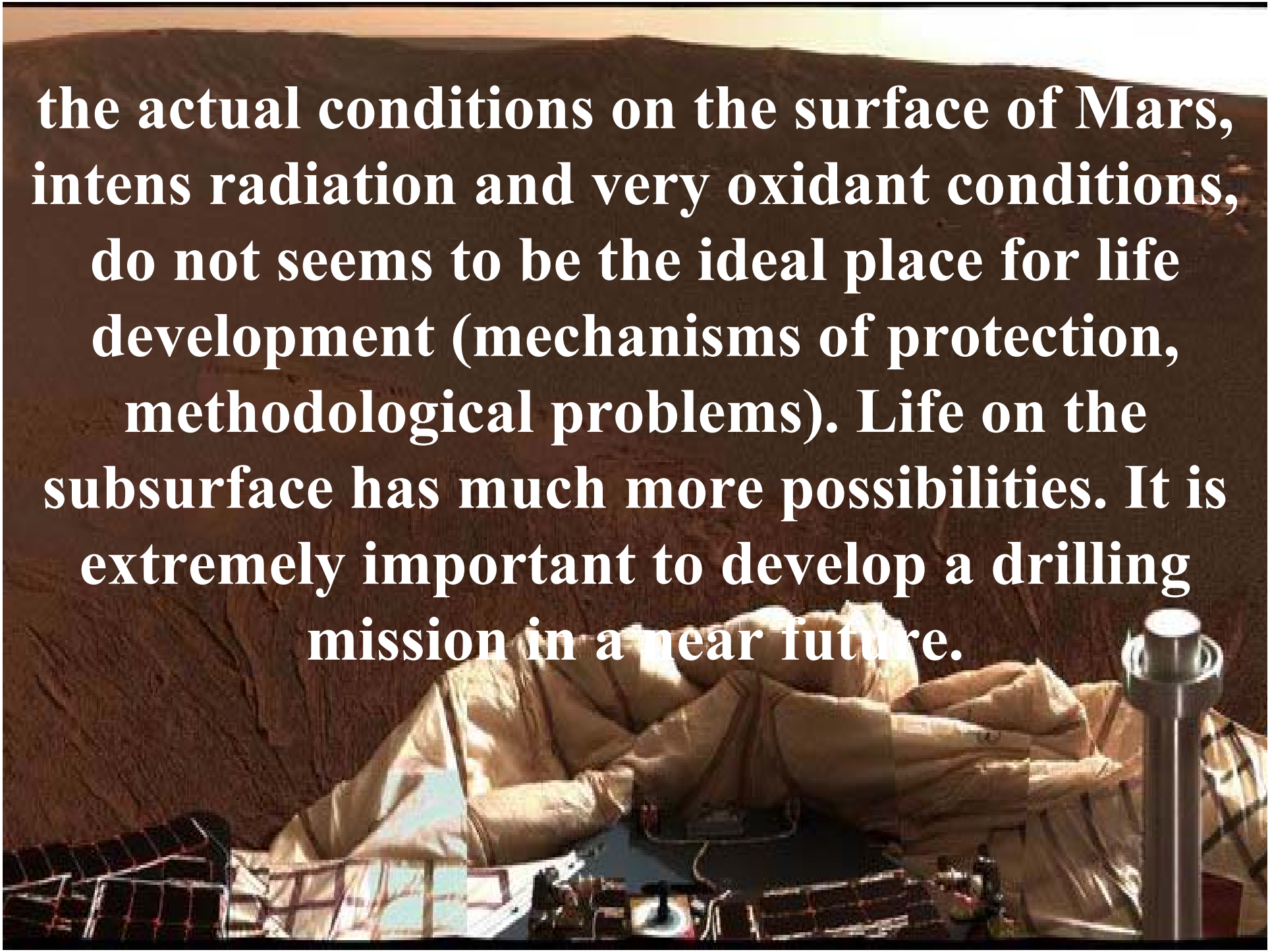
enrichment cultures in nonmethanogenic conditions: low pH, high positive redox potentials and high concentration of sulfate, produce methane after reduction of ferric iron and an increase in the pH

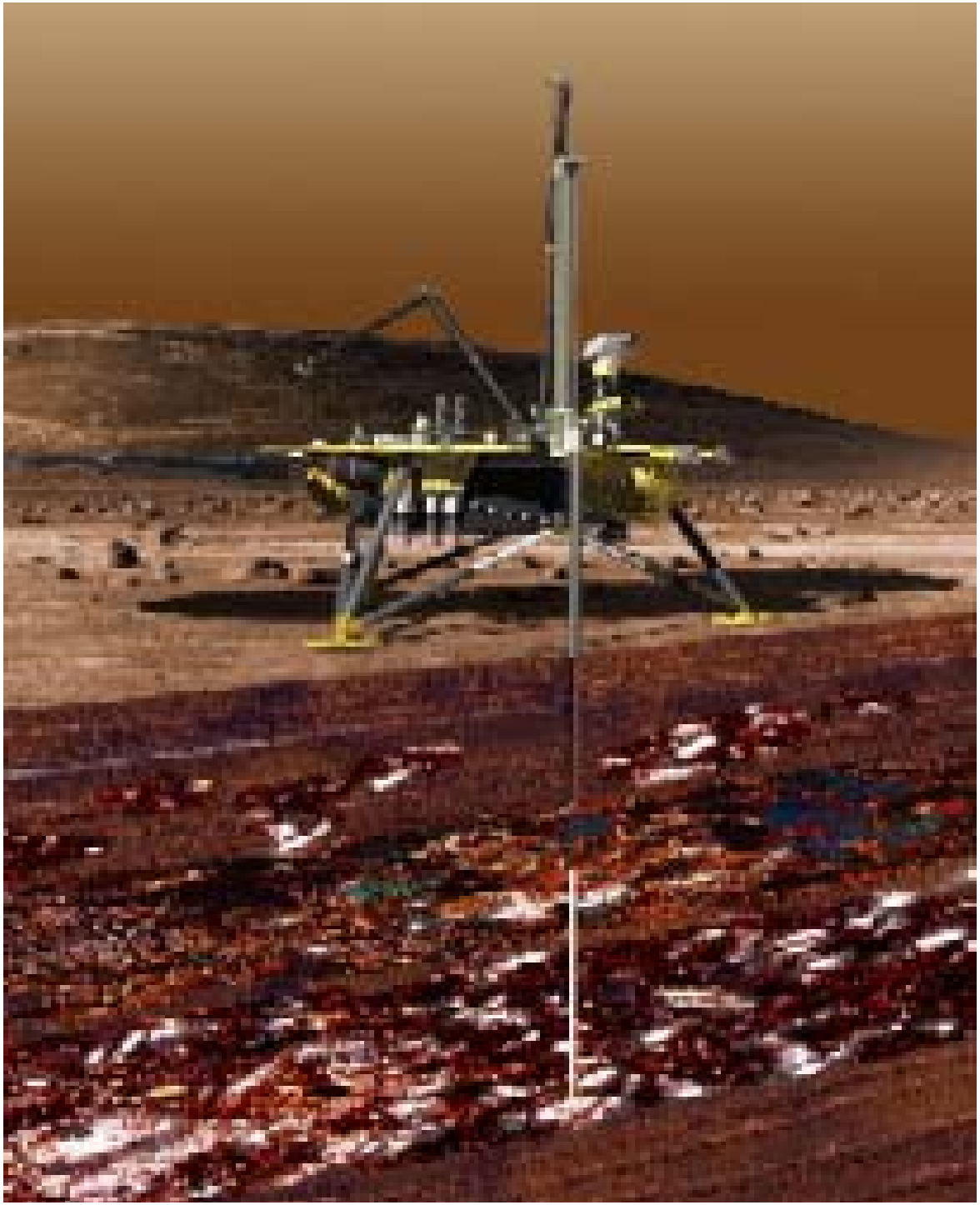

identified methanogens in Río Tinto sediments: *Methanosaeta concilii* (black bands)
Methanobacterium bryantii (H_2)
Methanosarcina barkeri (methanol)
JULIO SEGURA
PHOTOGRAPHY

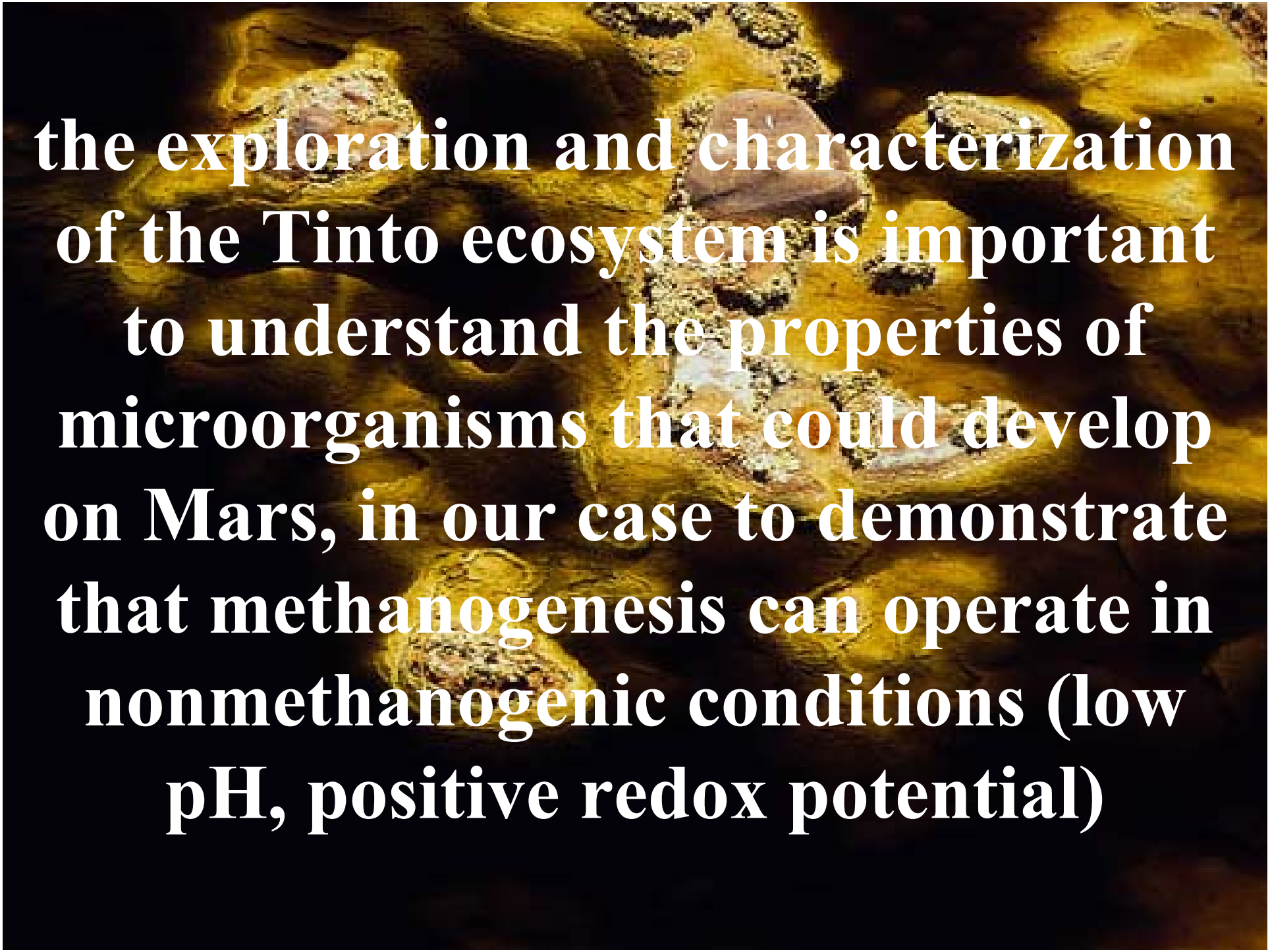

how to explain the operation of methanogens in this conditions?
microniches

comparison between MERIDIANI PLANUM and RIO TINTO

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


the actual conditions on the surface of Mars, intens radiation and very oxidant conditions, do not seems to be the ideal place for life development (mechanisms of protection, methodological problems). Life on the subsurface has much more possibilities. It is extremely important to develop a drilling mission in a near future.




the exploration and characterization of the Tinto ecosystem is important to understand the properties of microorganisms that could develop on Mars, in our case to demonstrate that methanogenesis can operate in nonmethanogenic conditions (low pH, positive redox potential)

Acknowledgements: 20 years of graduate students (Anabel López-Archilla)
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