Habitability: biological point of view

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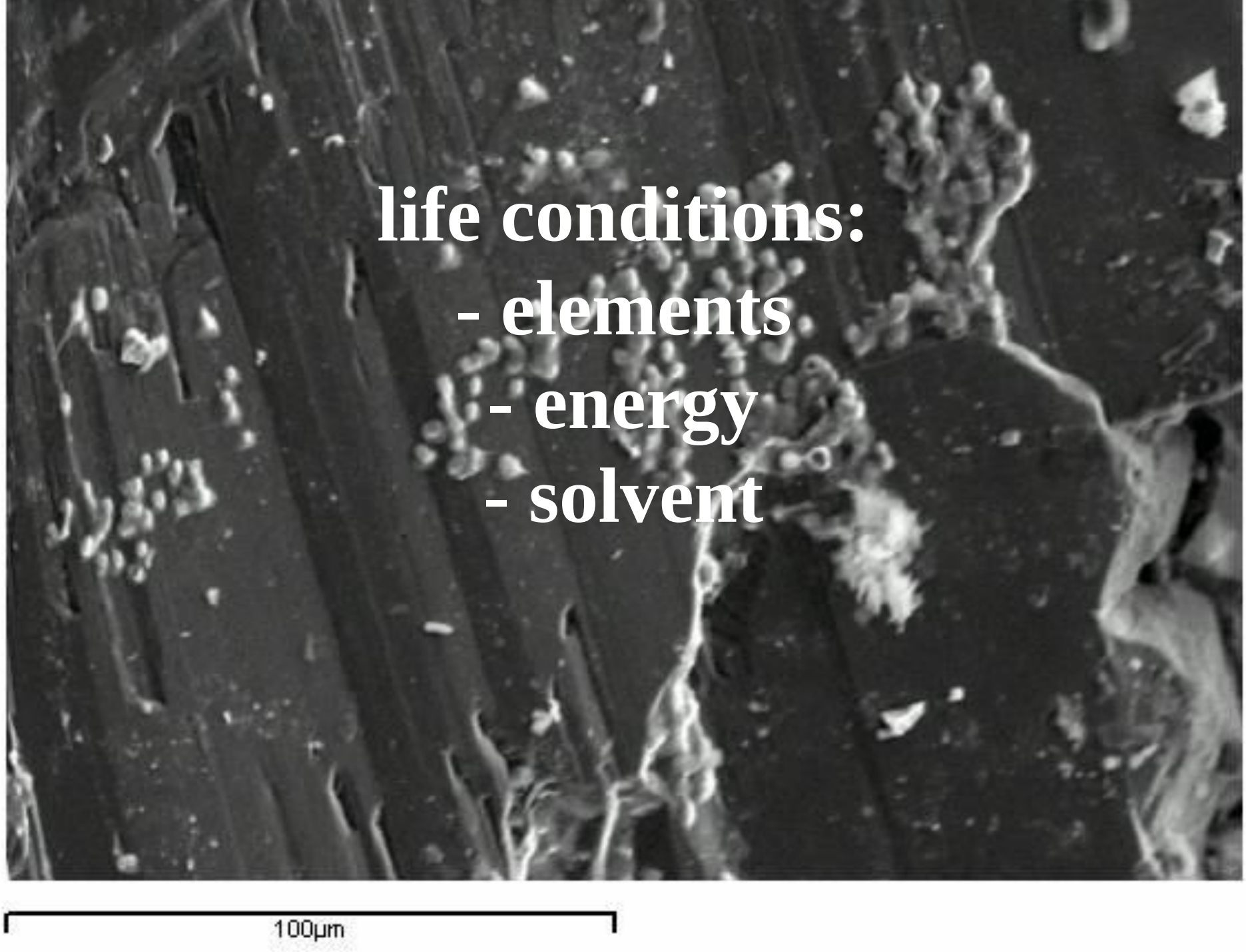


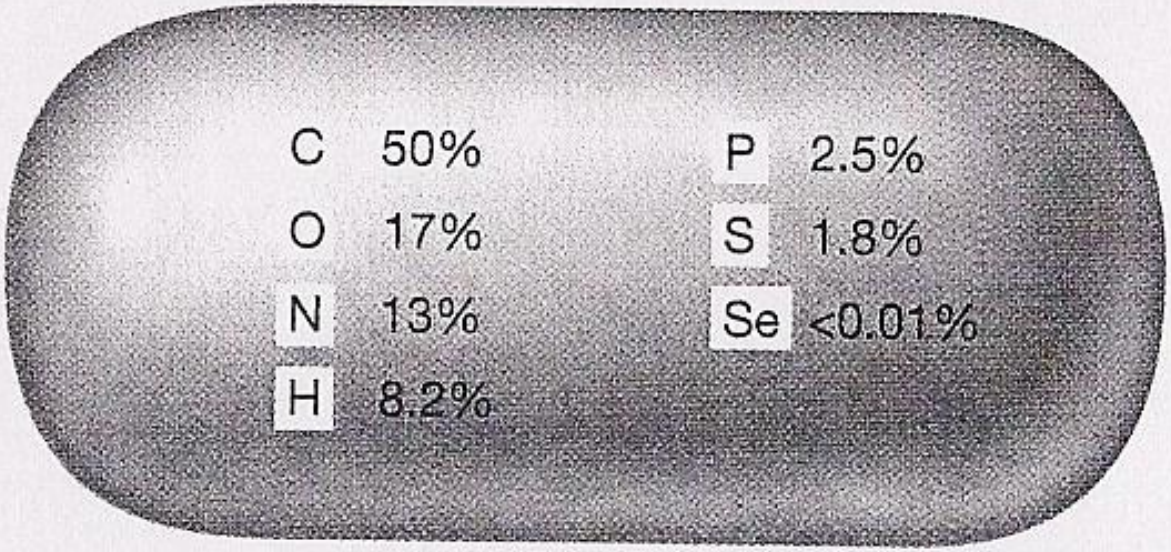
life conditions:

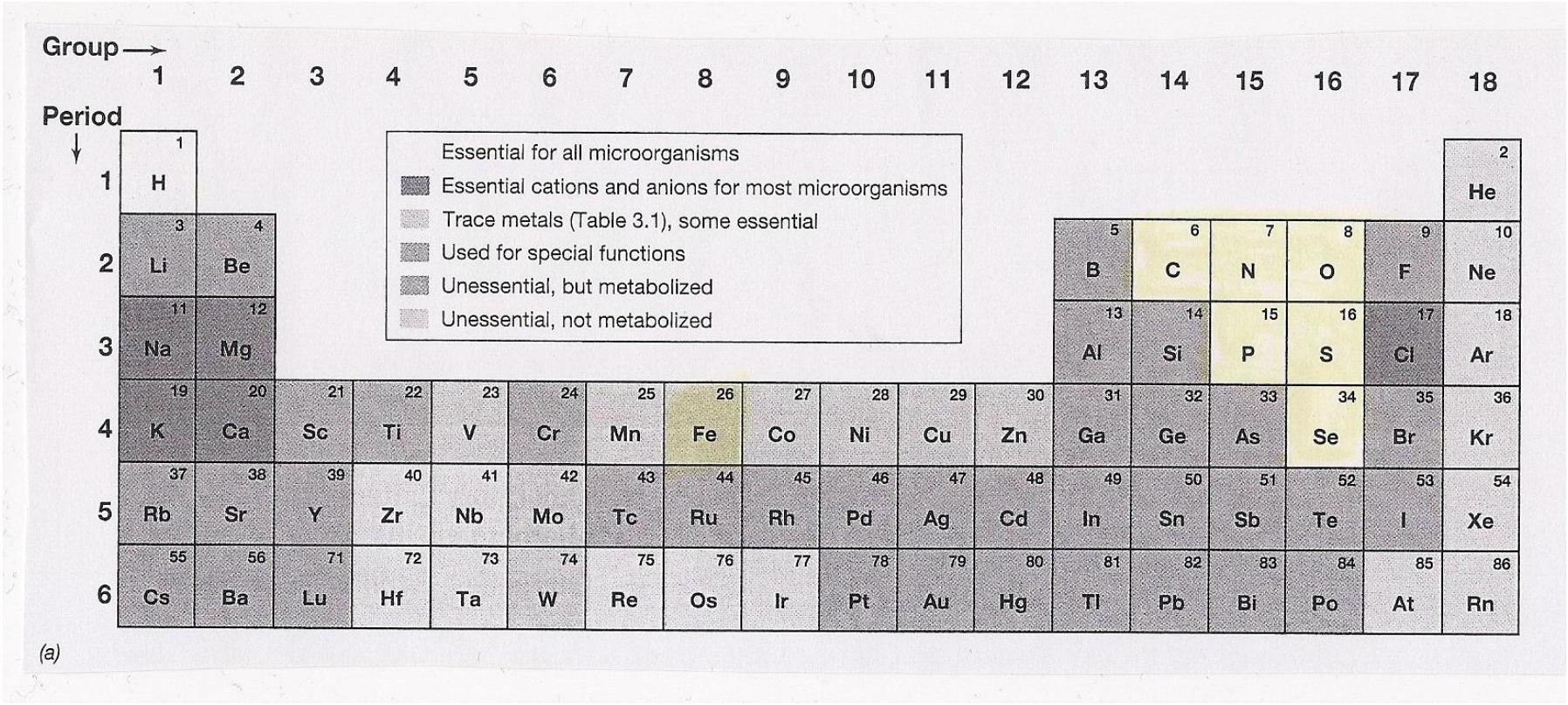
- elements

- energy

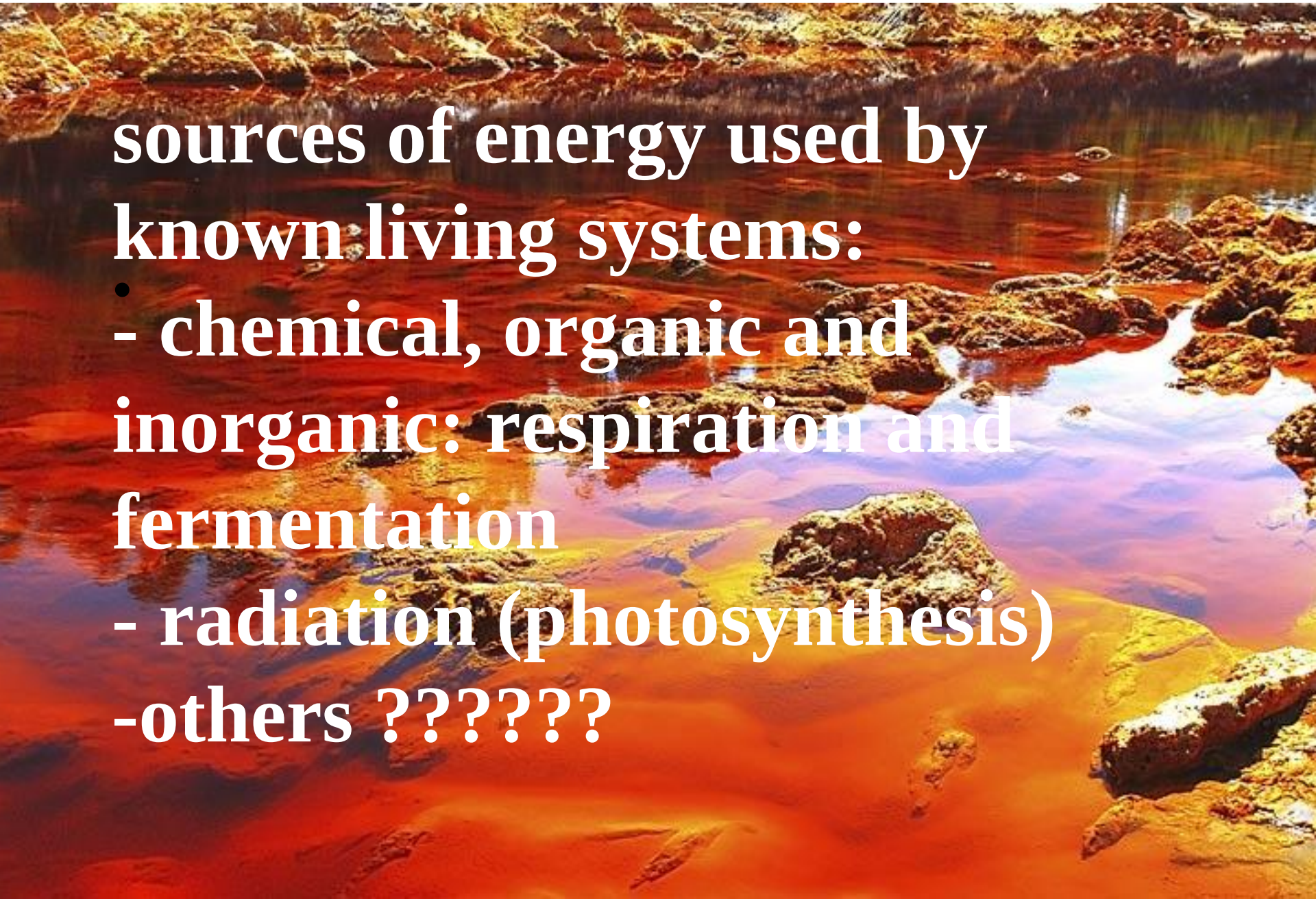
- solvent

Essential elements as a percent of cell dry weight




Group →
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Period ↓
1 H He
2 Li Be B C N O F Ne
3 Na Mg Al Si P S Cl Ar
4 K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr
5 Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe
6 Cs Ba Lu Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn
Essential for all microorganisms
Essential cations and anions for most microorganisms
Trace metals (Table 3.1), some essential
Used for special functions
Unessential, but metabolized
Unessential, not metabolized

(a)



sources of energy used by known living systems:

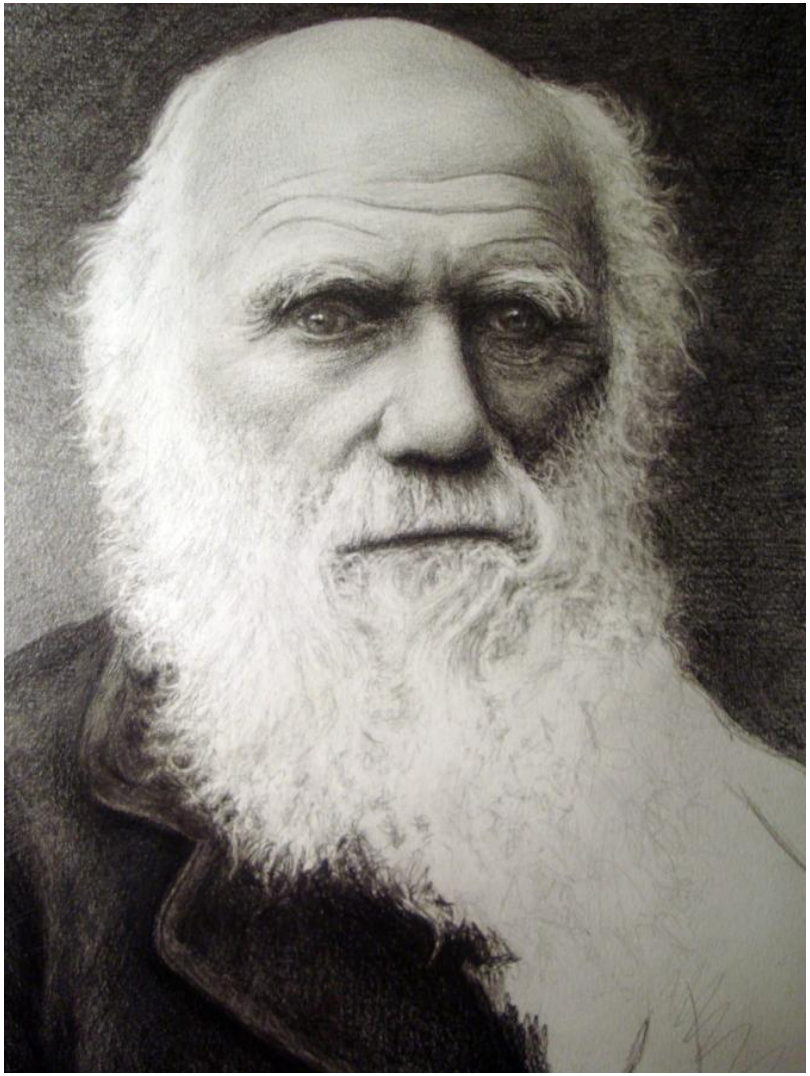
- chemical, organic and inorganic: respiration and fermentation
- radiation (photosynthesis)
-others ??????

solvents:

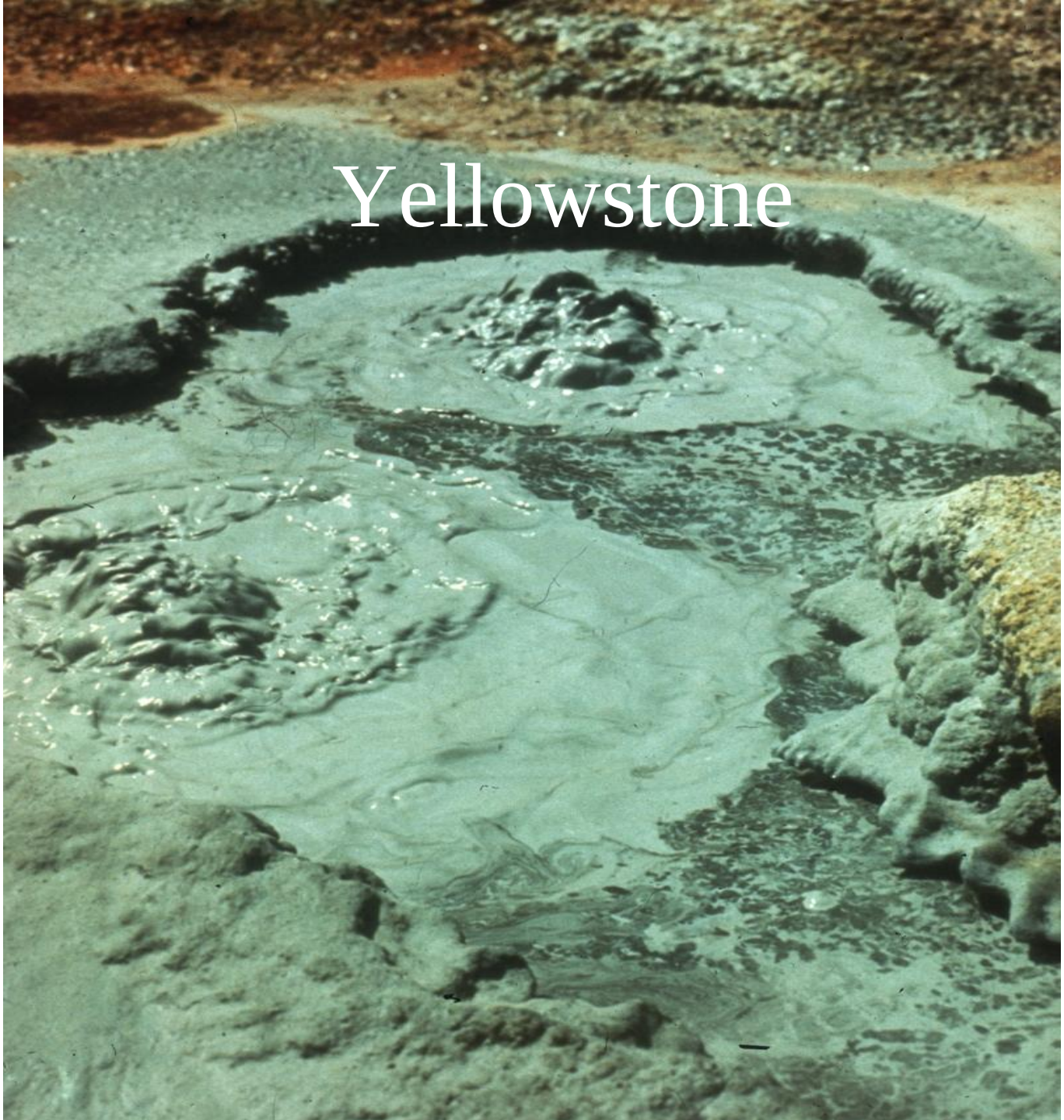
-H_2O

- NH_3, CH_4, others?

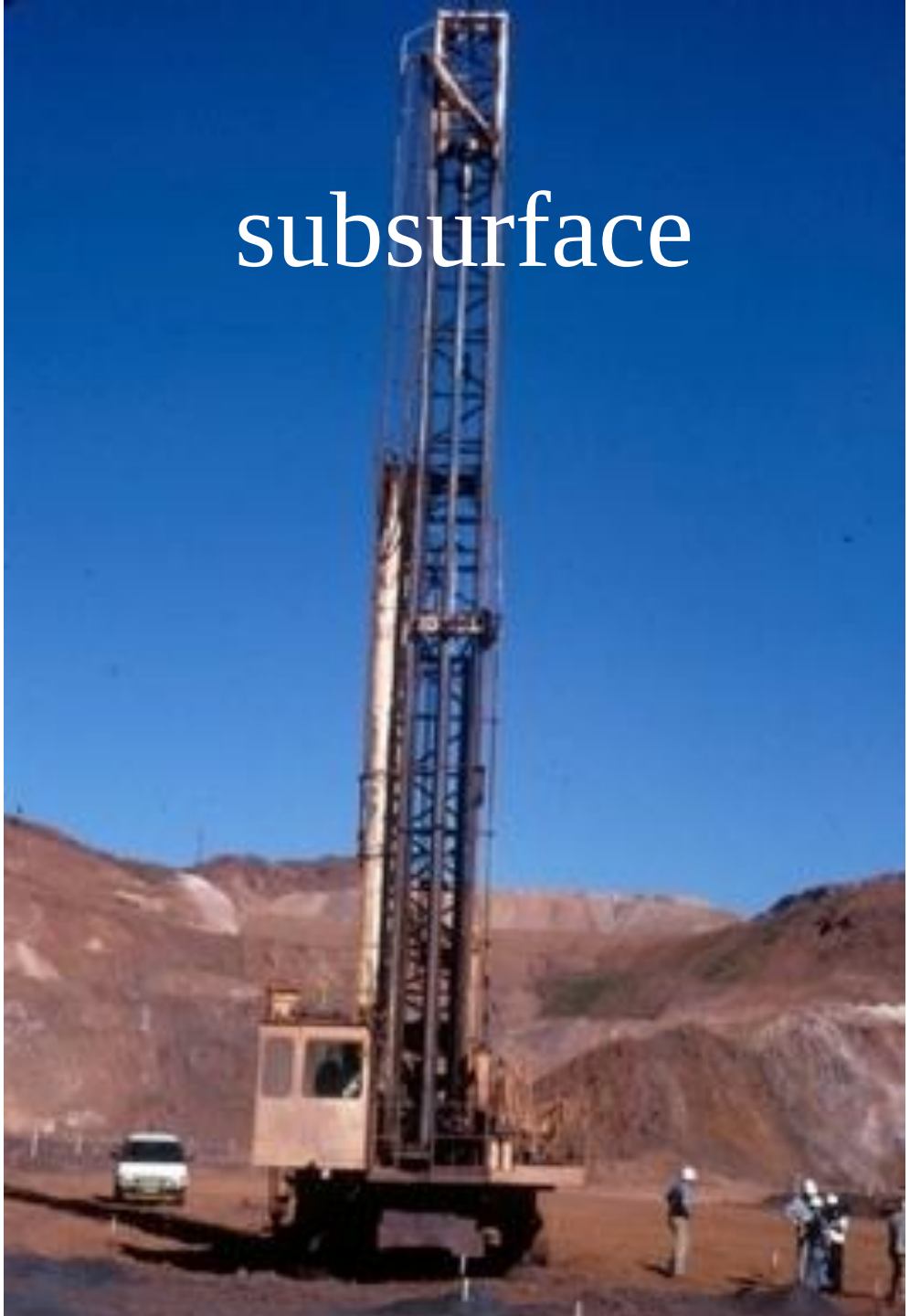
pioneer of extremofiles




Salar de Uyuni, Bolivia


Yellowstone

Vostok, Antártida

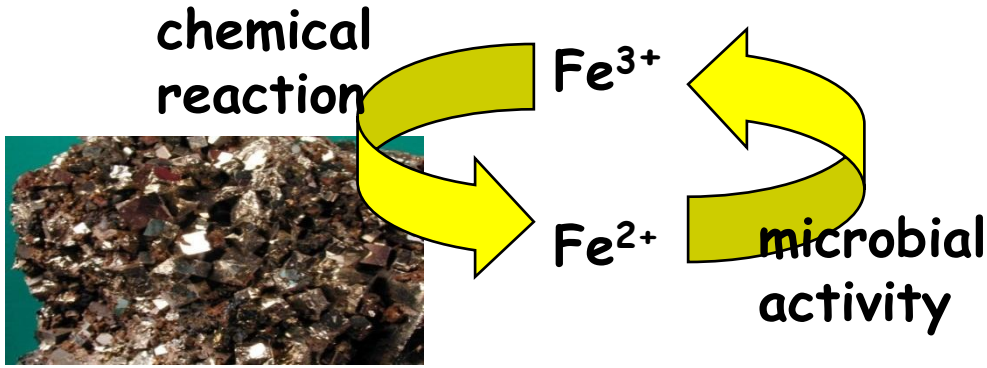

subsurface


extreme acidic environments

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

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

role of the microbial activity in the leaching of pyrite

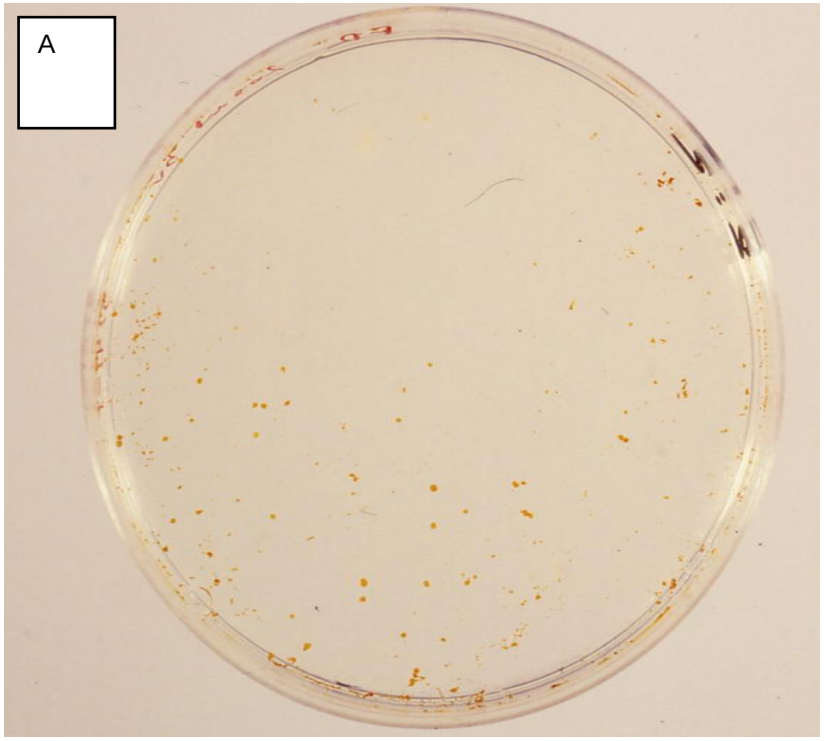


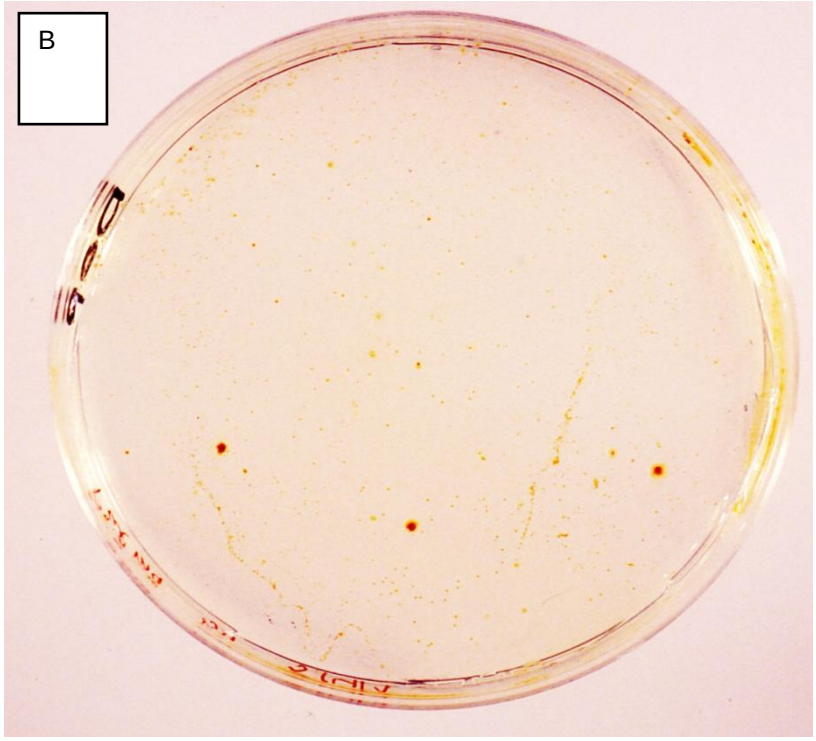
$SO_4^{2-} + H^+$

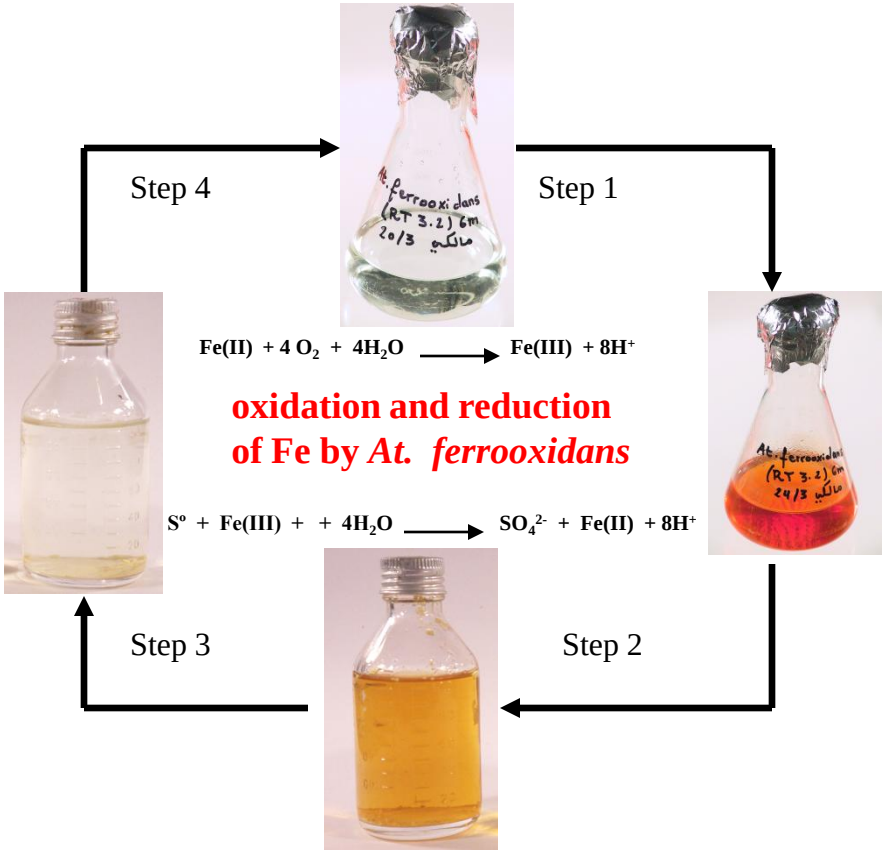

rio Tinto

geoMICROBIOLOGY

limitations of the conventional microbial ecology: isolation of Fe oxidizing bacteria



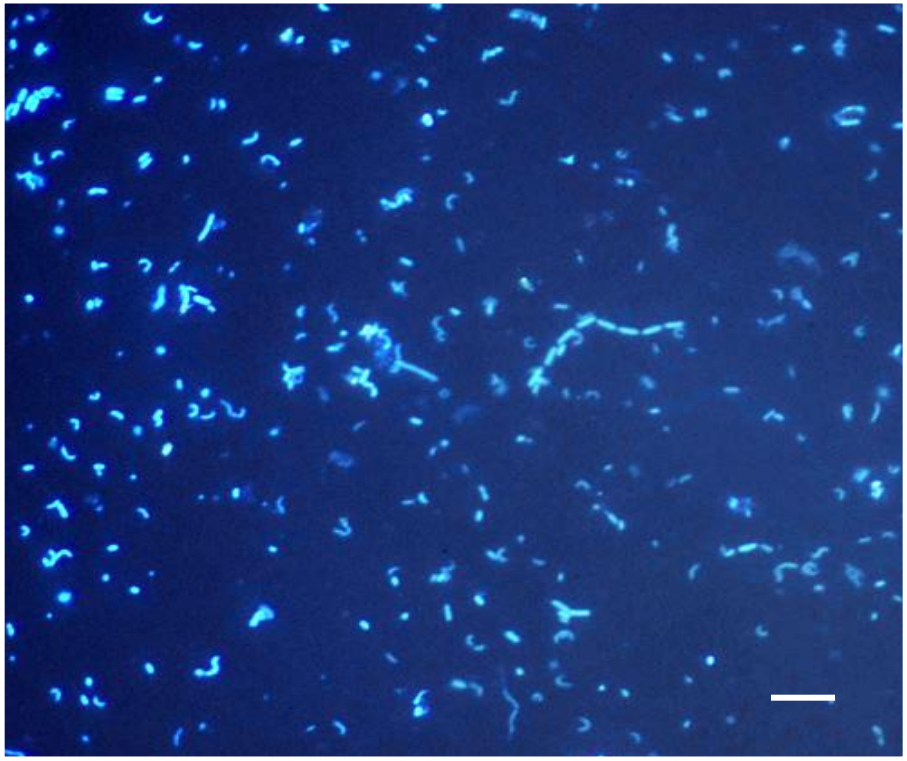



Step 4
Step 1
Step 3
Step 2
$Fe(II) + 4\,O_2 + 4H_2O \longrightarrow Fe(III) + 8H^+$
oxidation and reduction
of Fe by *At. ferrooxidans*
$S^o + Fe(III) + + 4H_2O \longrightarrow SO_4^{2-} + Fe(II) + 8H^+$

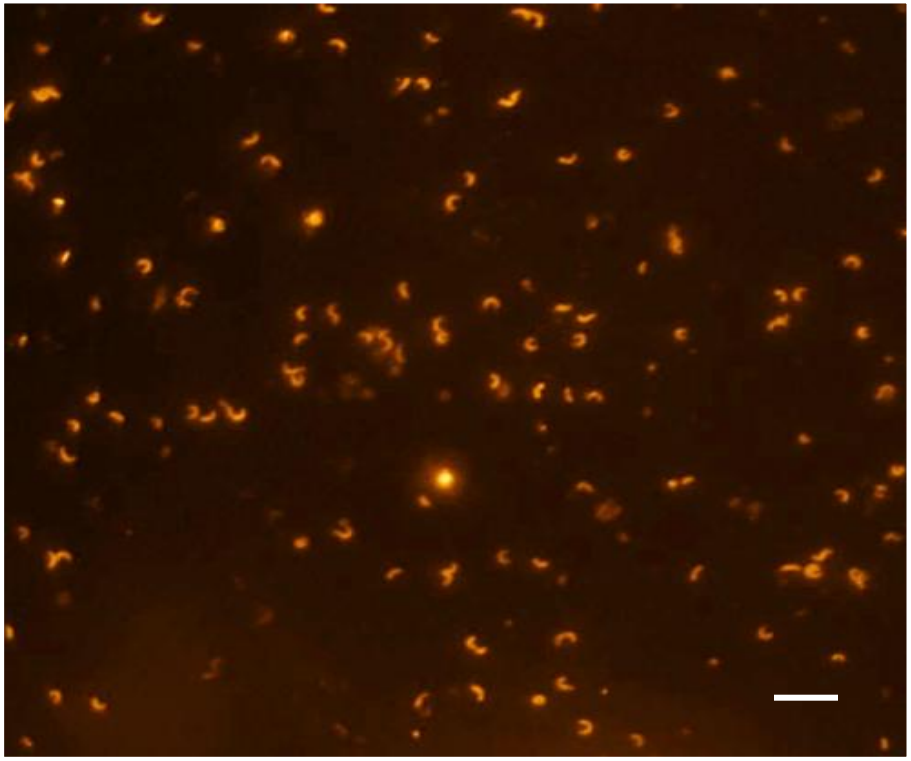
the irruption of molecular biology techniques into microbial ecology has produced an authentic revolution

phylogeny of acidophilic microorganisms detected in Rio Tinto

fluorescence in situ hybridization (FISH)

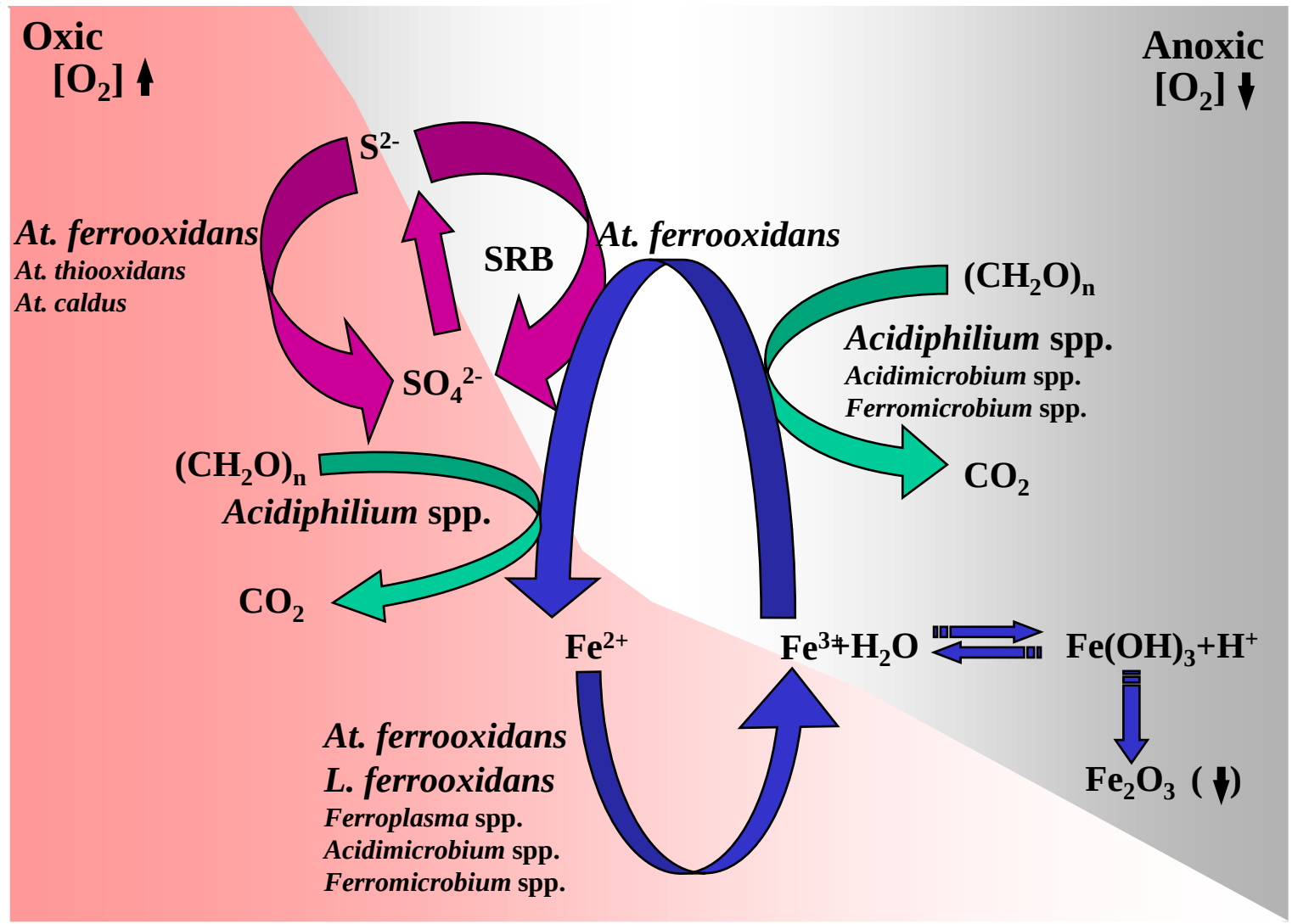


DAPI-stained cells

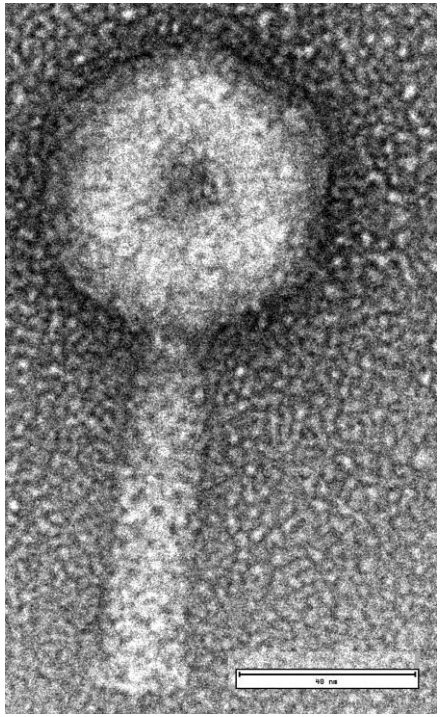


Cells hybridized with LEP636 probe (Cy3-labeled) specific for *L. ferrooxidans*

geomicrobiological model of Río Tinto water column

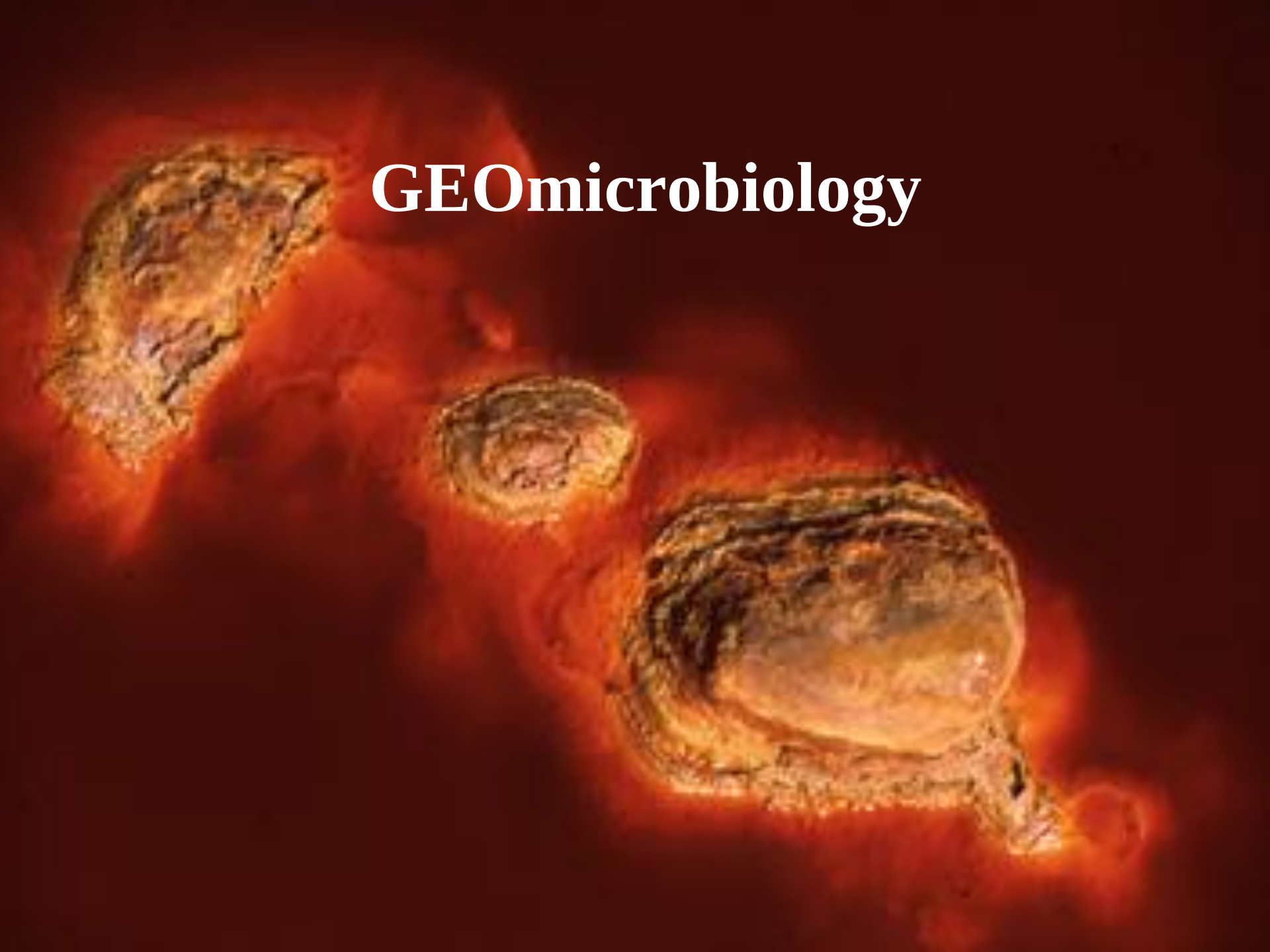


Acidophilic bacteriophages from Rio Tinto

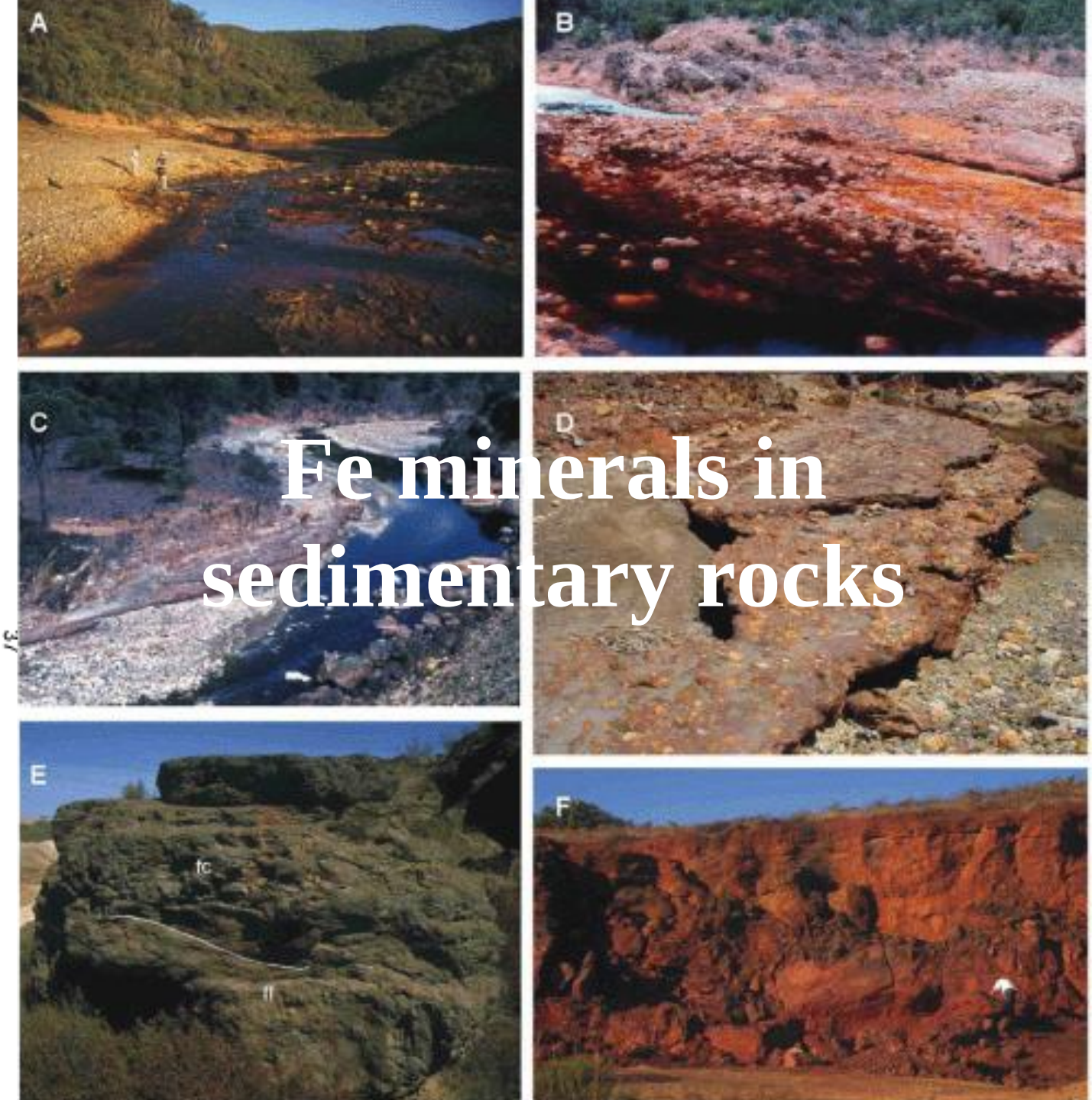


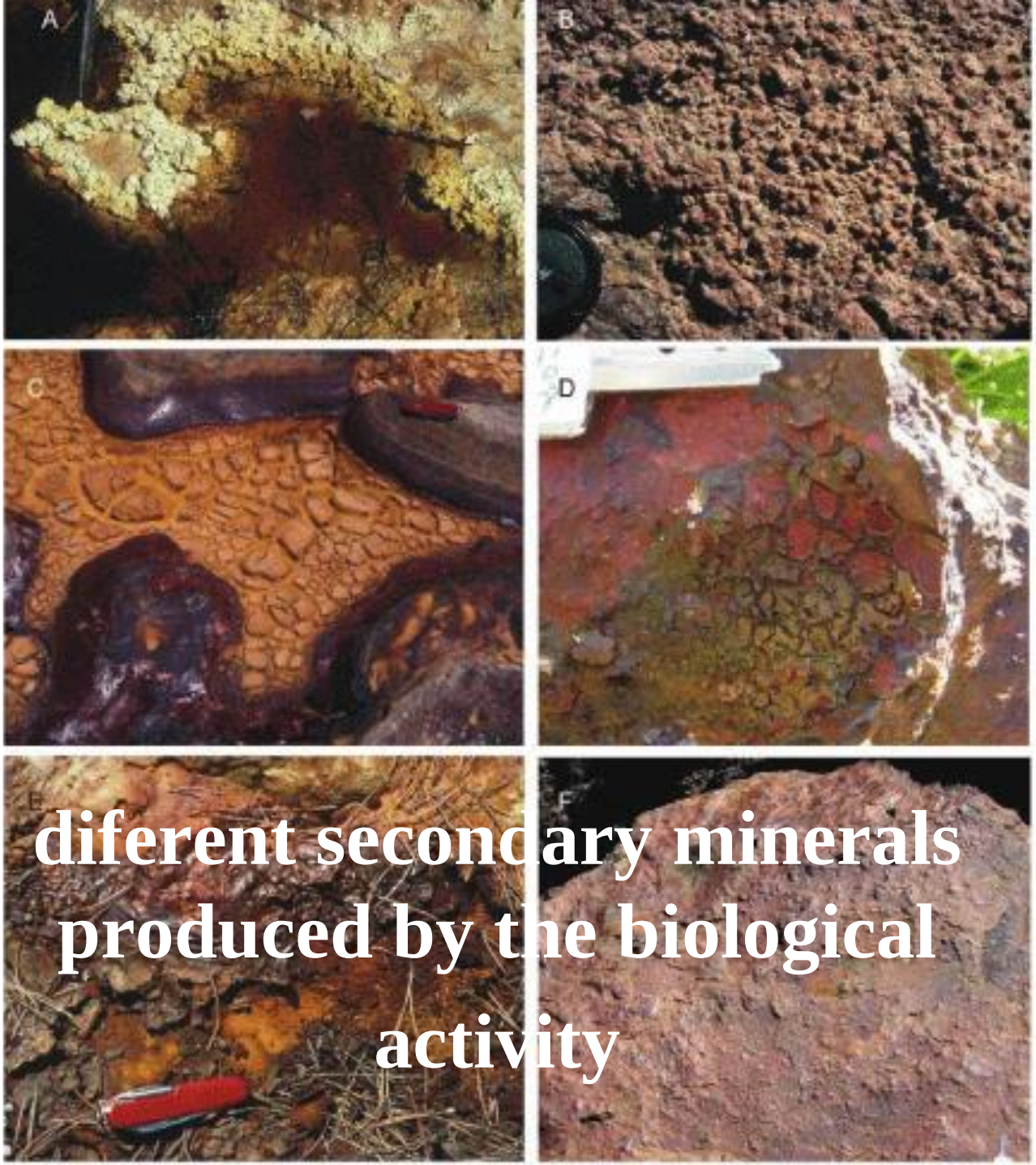
Phage ACD-RT1 – a myovirus infecting *Acidiphilium* sp., both host and phage isolated from Rio Tinto.

GEOmicrobiology



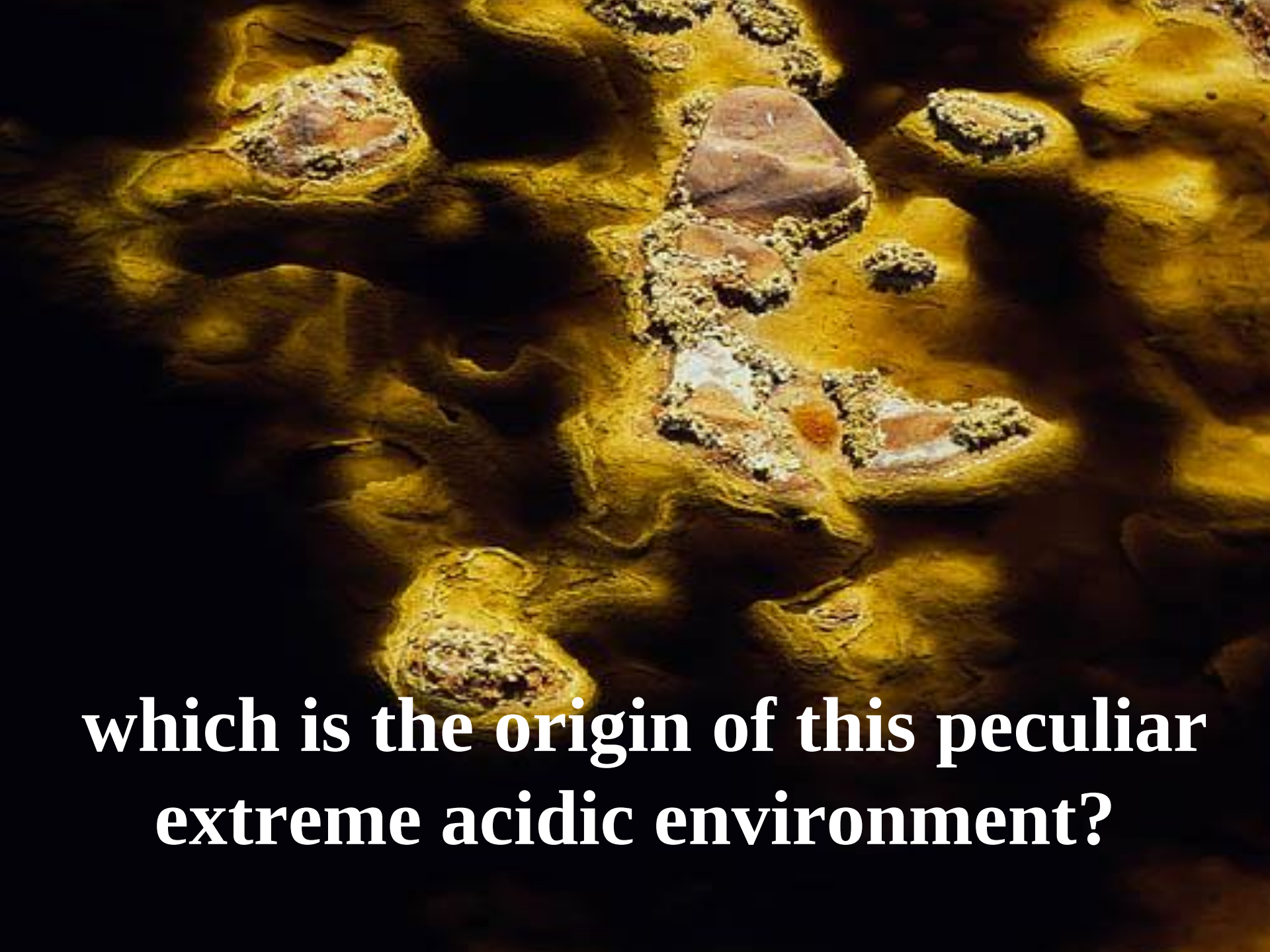
Fe minerals in sedimentary rocks





diferent secondary minerals produced by the biological activity


Fe deposits older than
2x10^6 years



which is the origin of this peculiar extreme acidic environment?

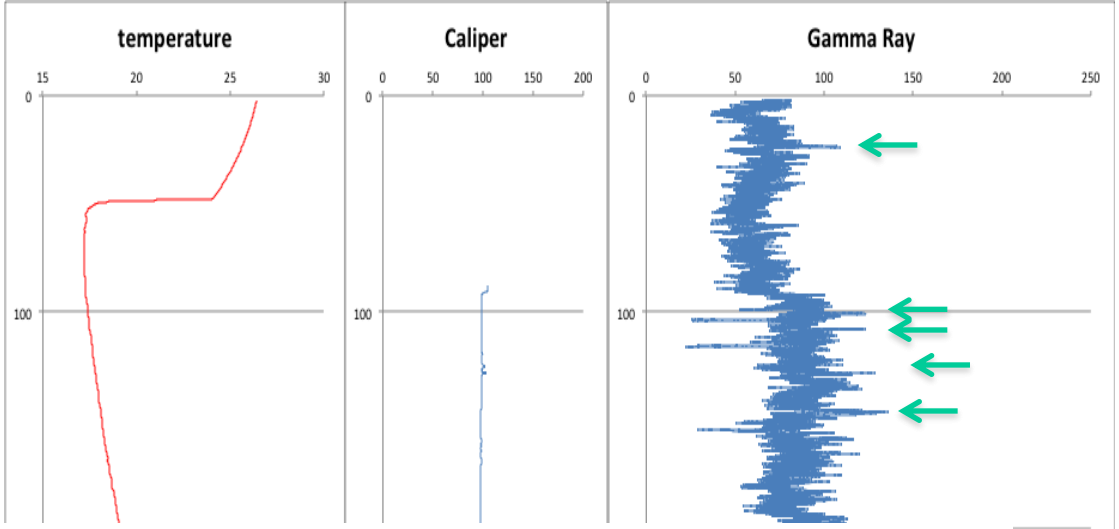
subsurface microbiology

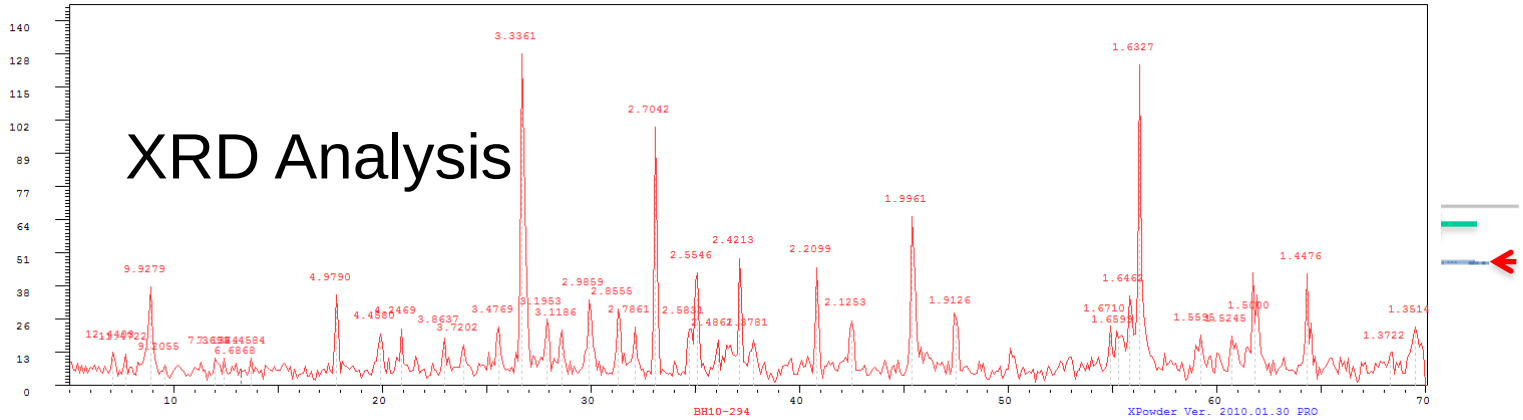
IPBSL

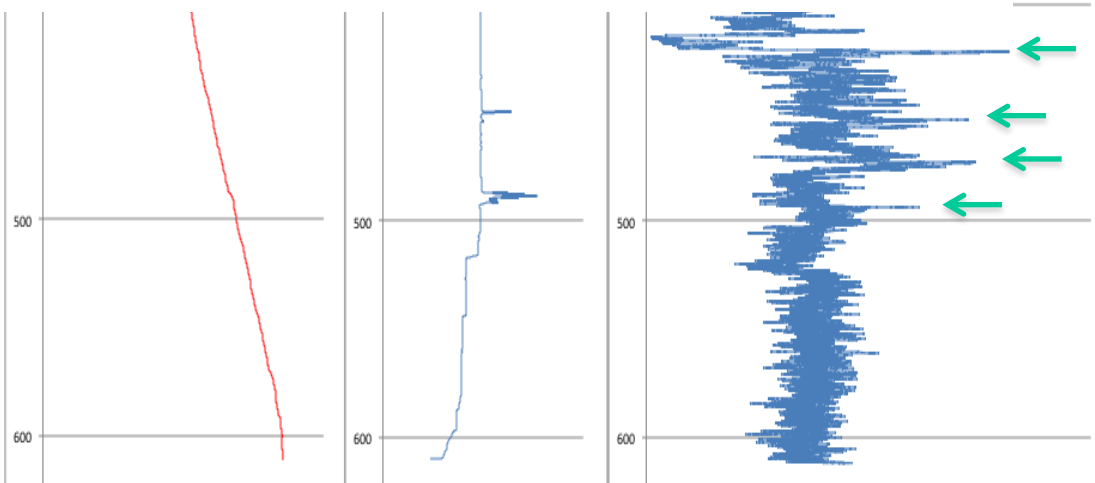
IBERIAN PYRITIC BELT SUBSURFACE LIFE DETECTION


HYDRASPLIT

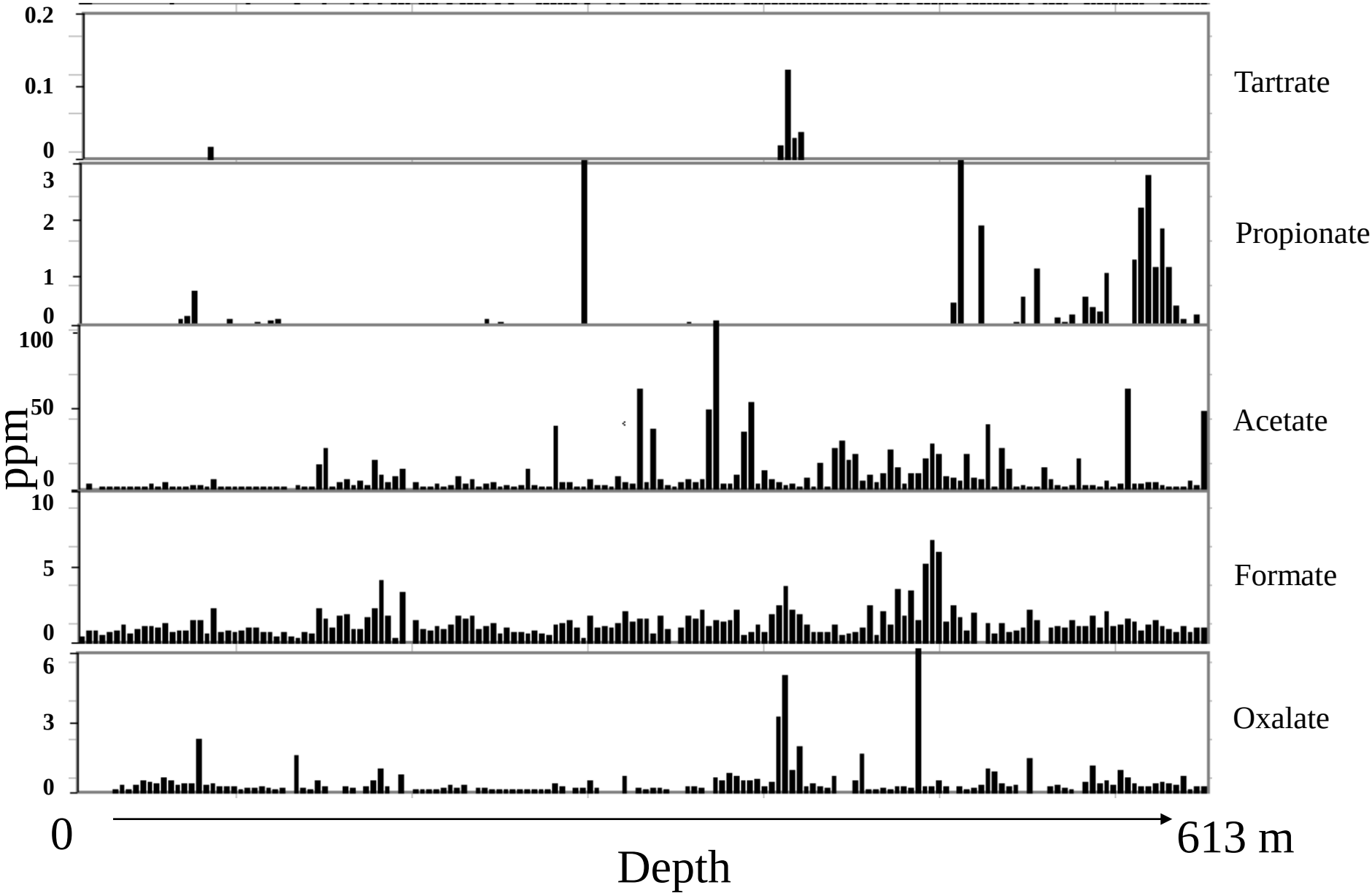
Profiling BH10 After



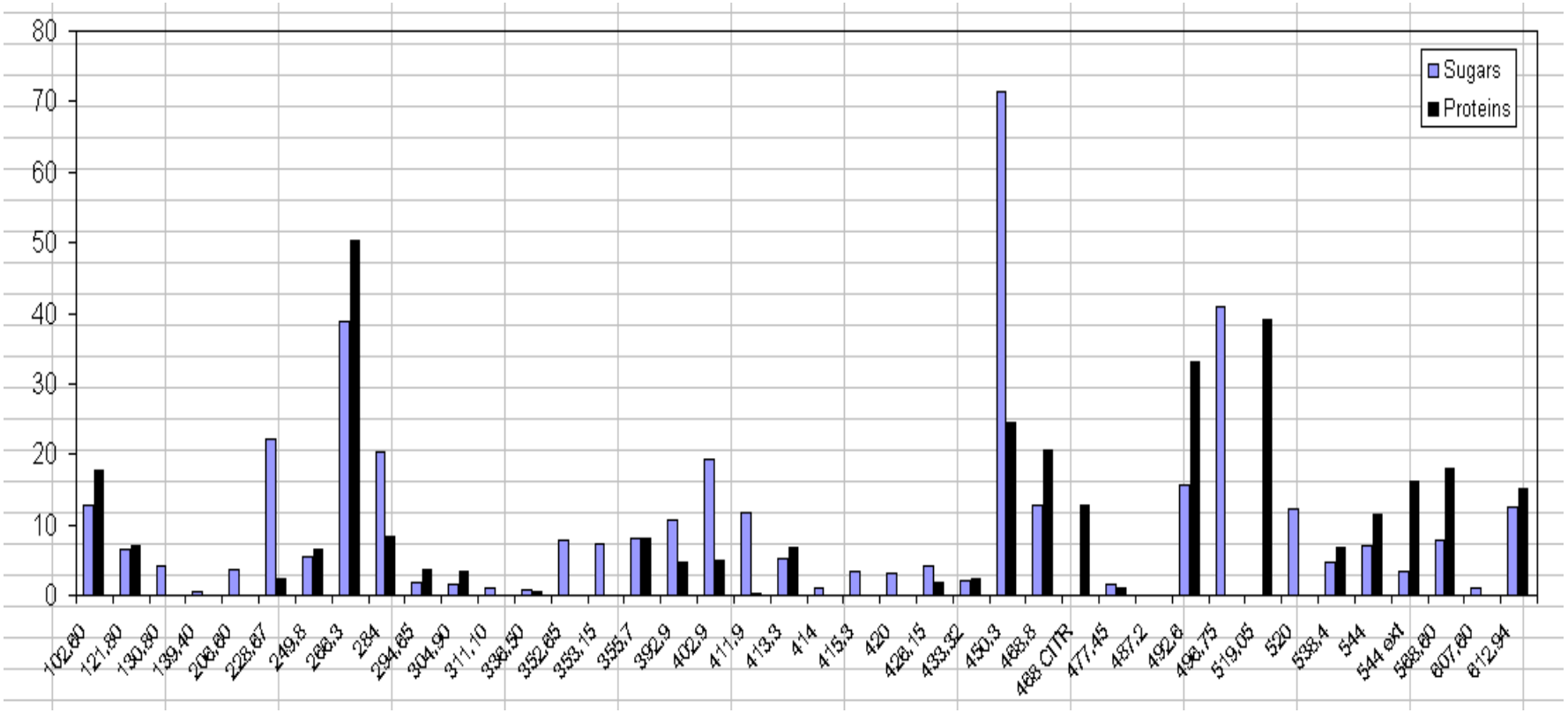




ion chromatography BH10, organic acids

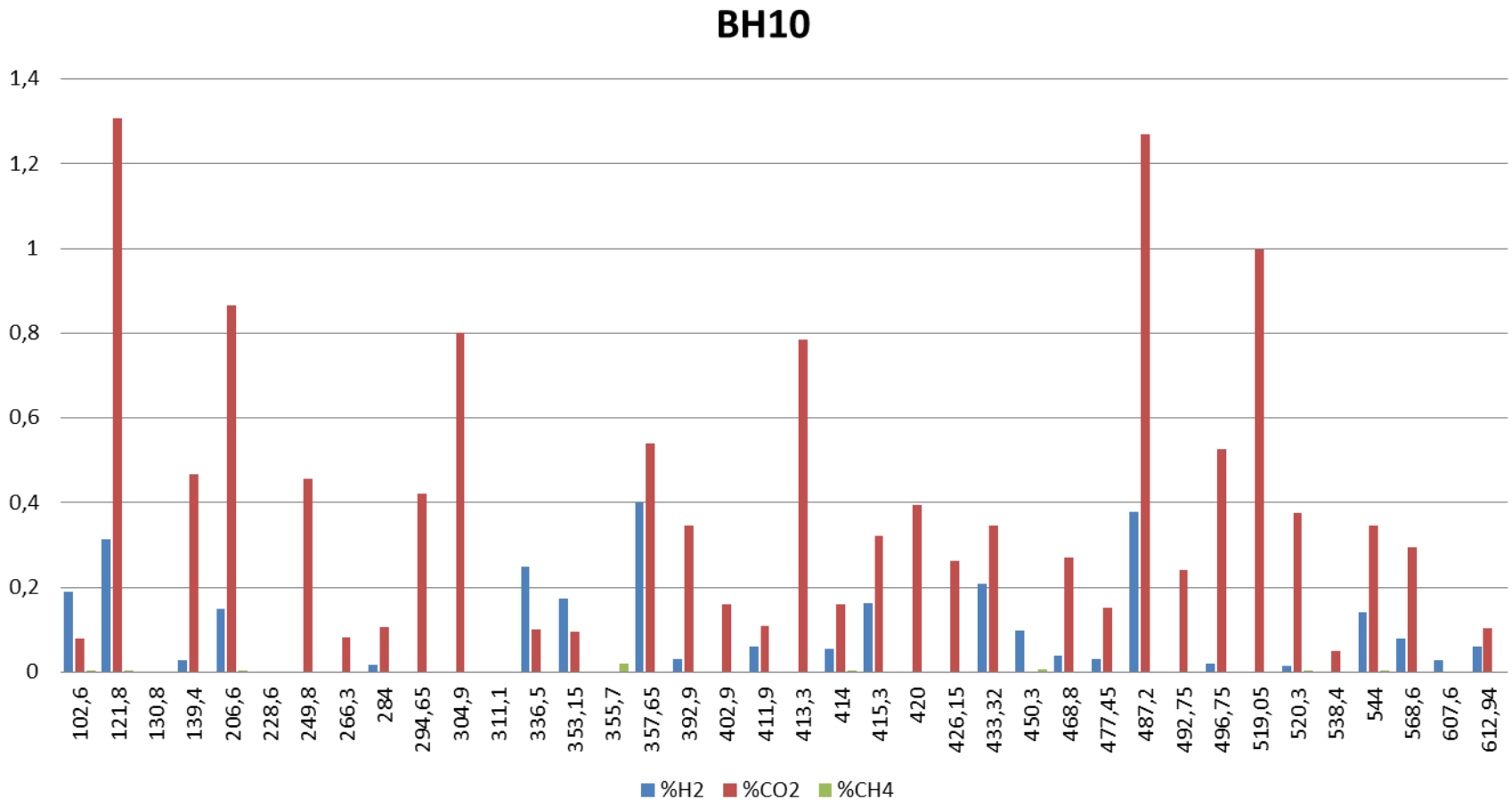


total proteins and sugars, BH10

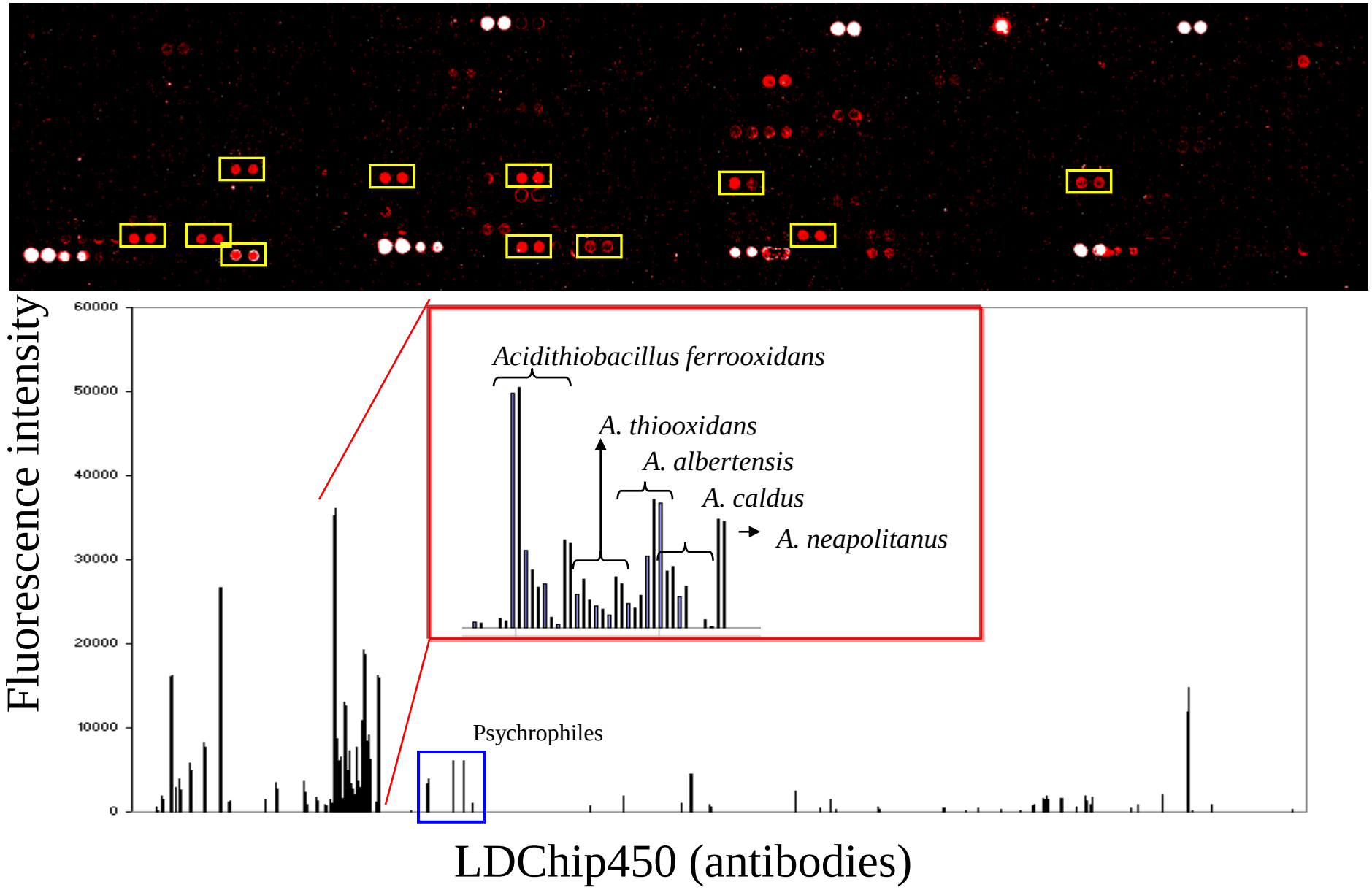


100 → **612**

gas chromatography



LD450Chip, -90m, BH10



enrichment cultures:

- pyrite, Fe and S oxidizers

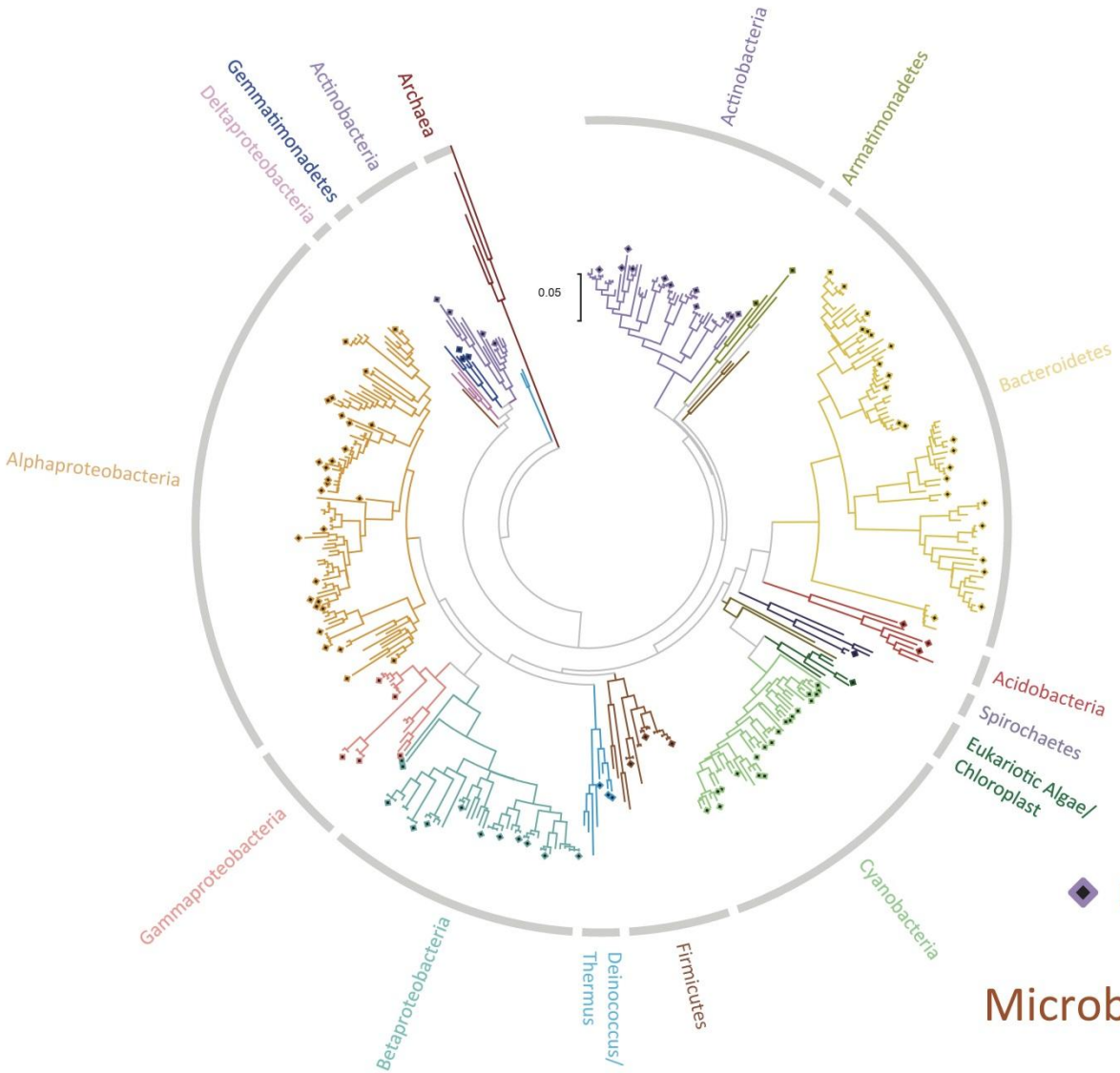
- Fe and sulfate reducers

-methanogens

- metanótrophs

- denitrifiers

- acetogenic bacteria

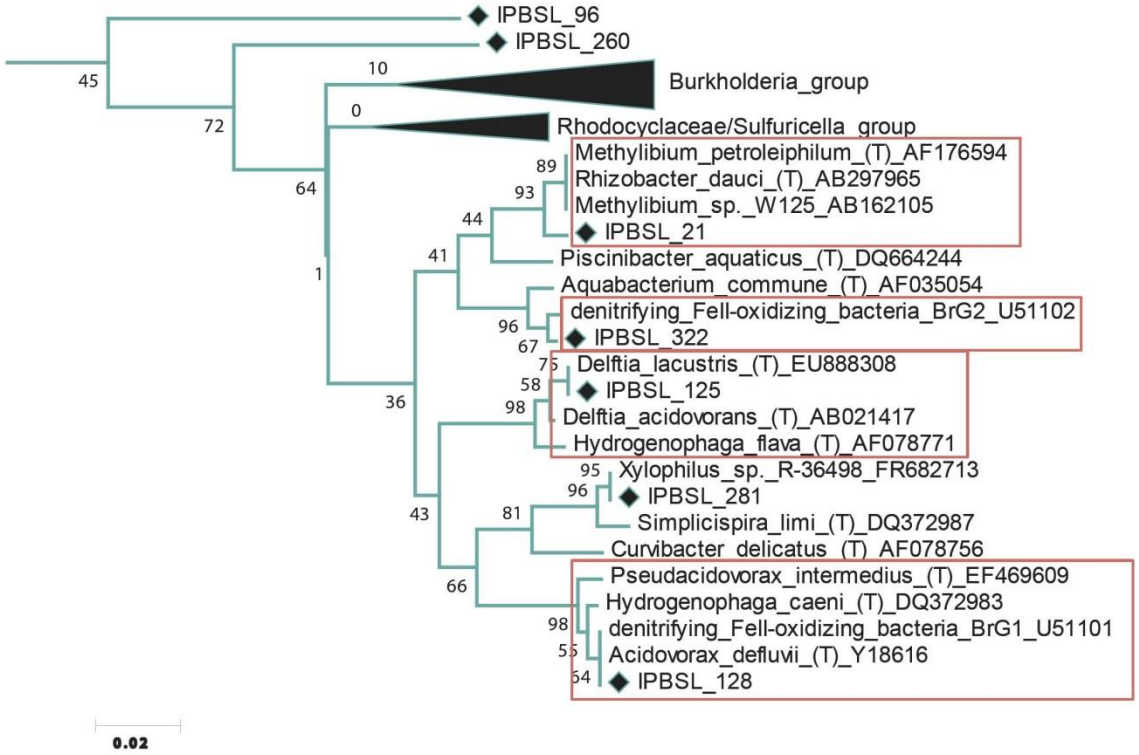


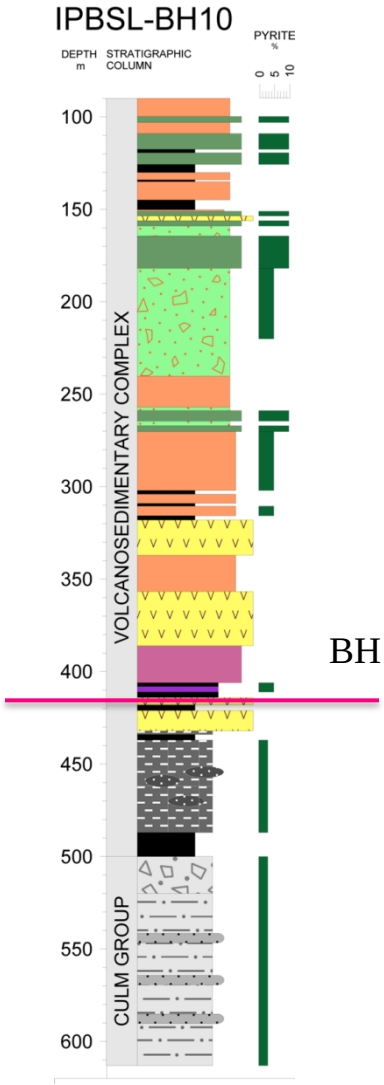
IPBSL samples
(120 OTUs)

Microbial diversity of Borehole 10

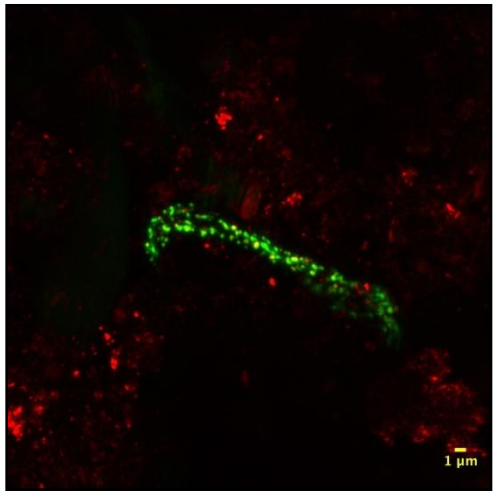
Some interesting OTUs

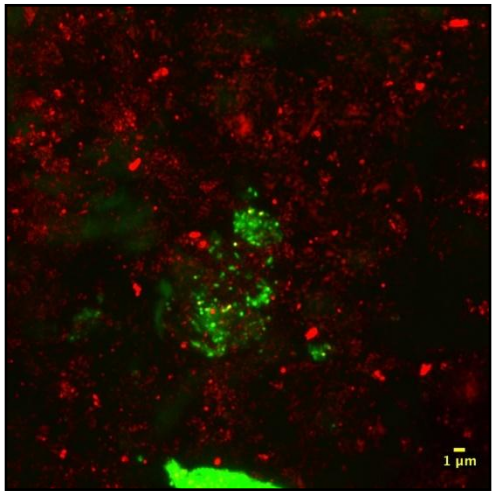
- Phylum: Proteobacteria (Beta)

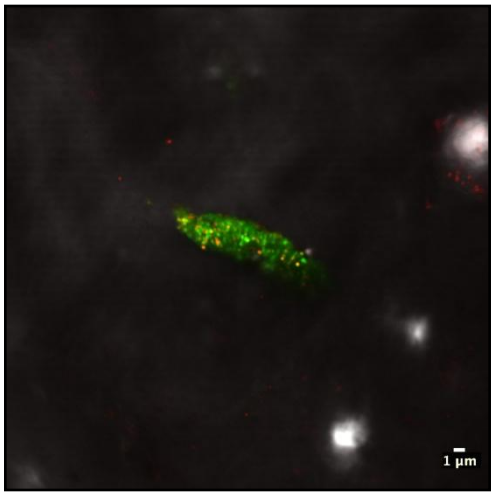




BH10-414,80







THIO820

BET42a
GAM42a

IPBSL

CARD-FISH

$4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$ B

$H_2 + SO_4^{2-} + H^+ \rightarrow HS^- + 4H_2O$ B

$Fe^{2+} + H_2S \rightarrow FeS + H_2$ Q

$FeS + H_2S \rightarrow H_2 + FeS_2$ Q

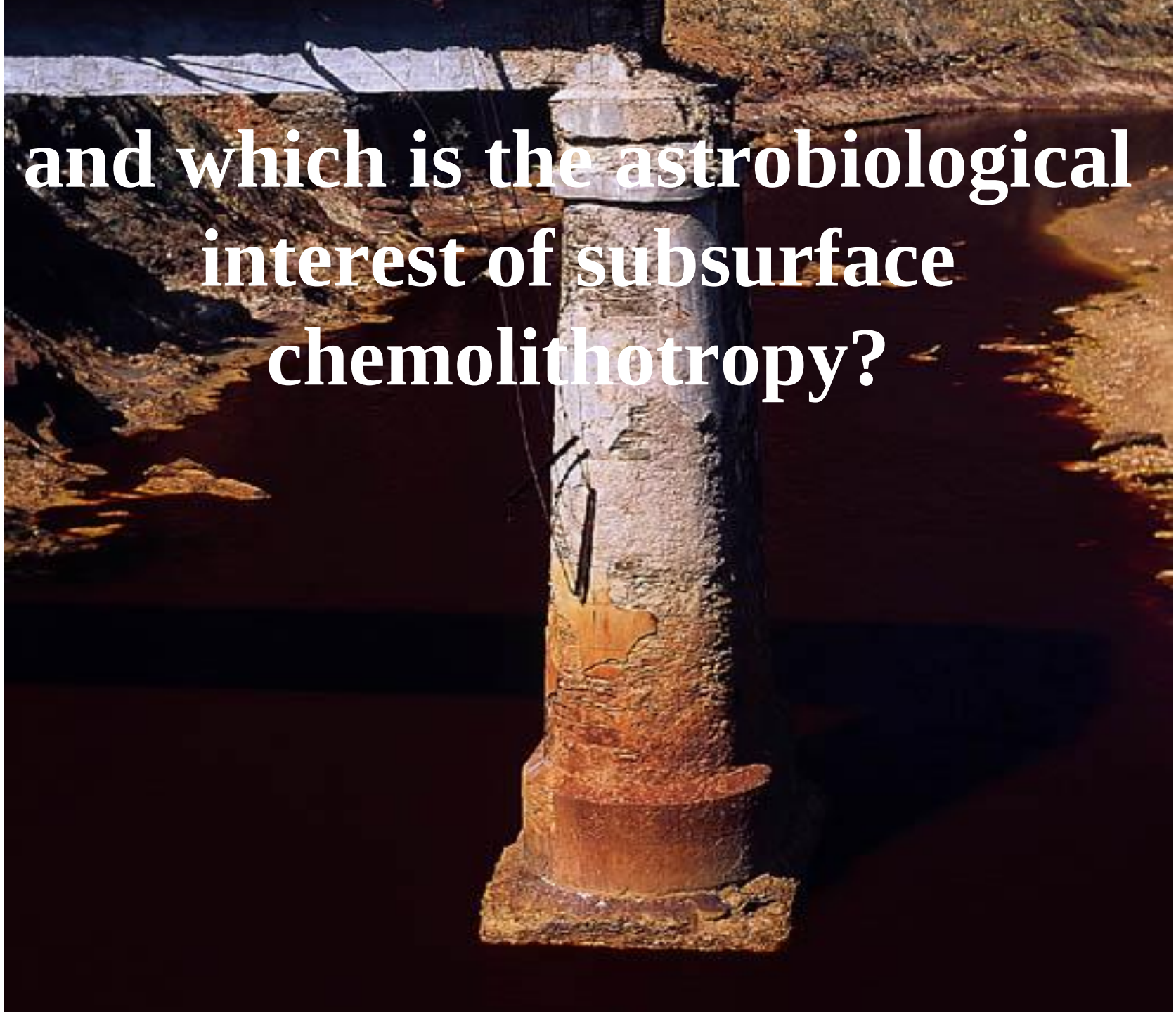
$FeS_2 + Fe^{3+} + 8H_2O \rightarrow 2SO_4^{2-} + Fe^{2+} + 16H^+$ Q

$Fe^{2+} + NO_3^- \rightarrow Fe^{3+} + NO_2^-$ B

$C_n(H_2O)_n + Fe^{3+} + H_2O \rightarrow CO_2 + Fe^{2} + 4H^+$ B

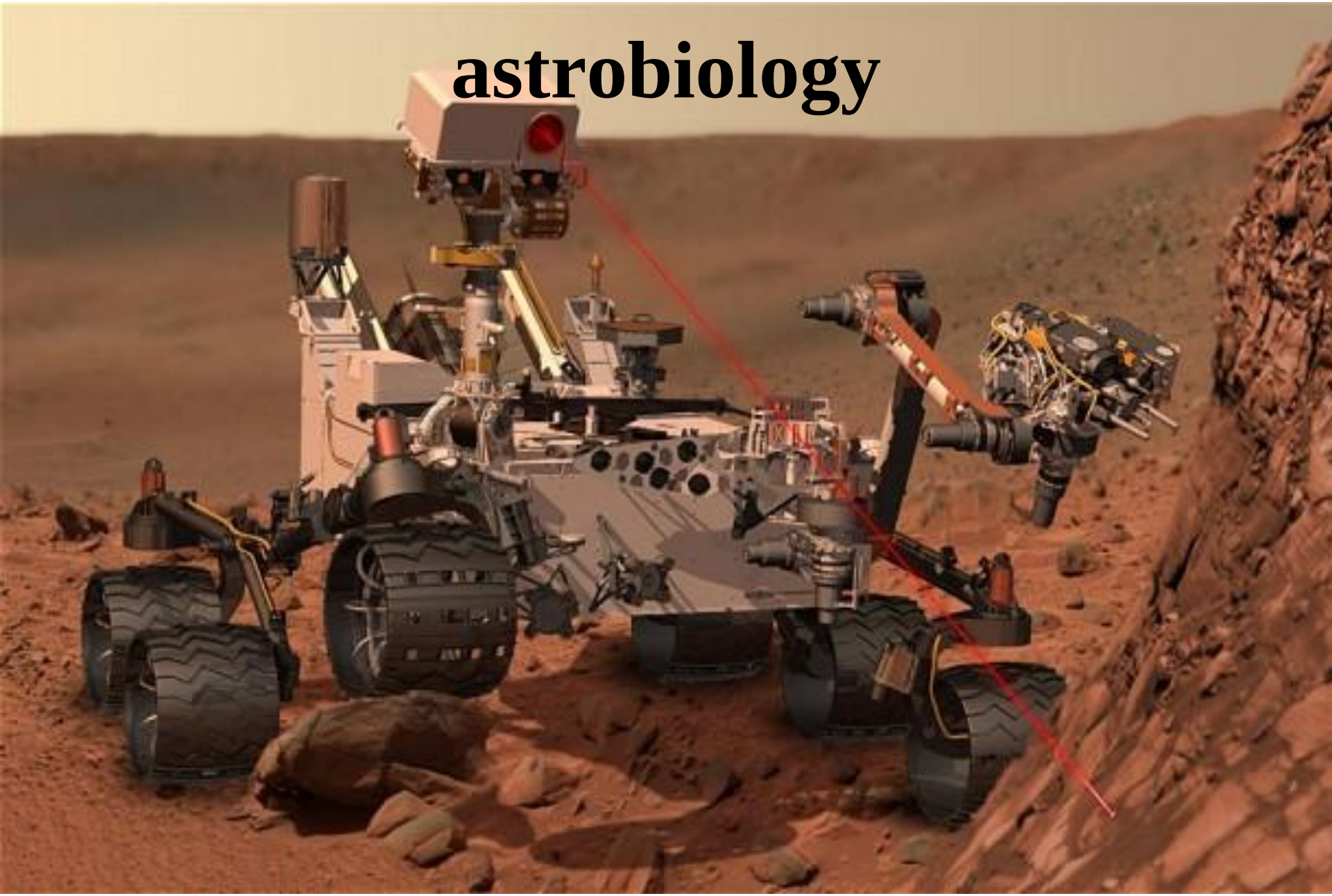
$H_2 + HCO_3^- + H^+ \rightarrow CH_3COO^- + H_2O$ B

$C_3H_6O_3 + SO_4^{2-} \rightarrow CH_3COO^- + S^{2-}$ B

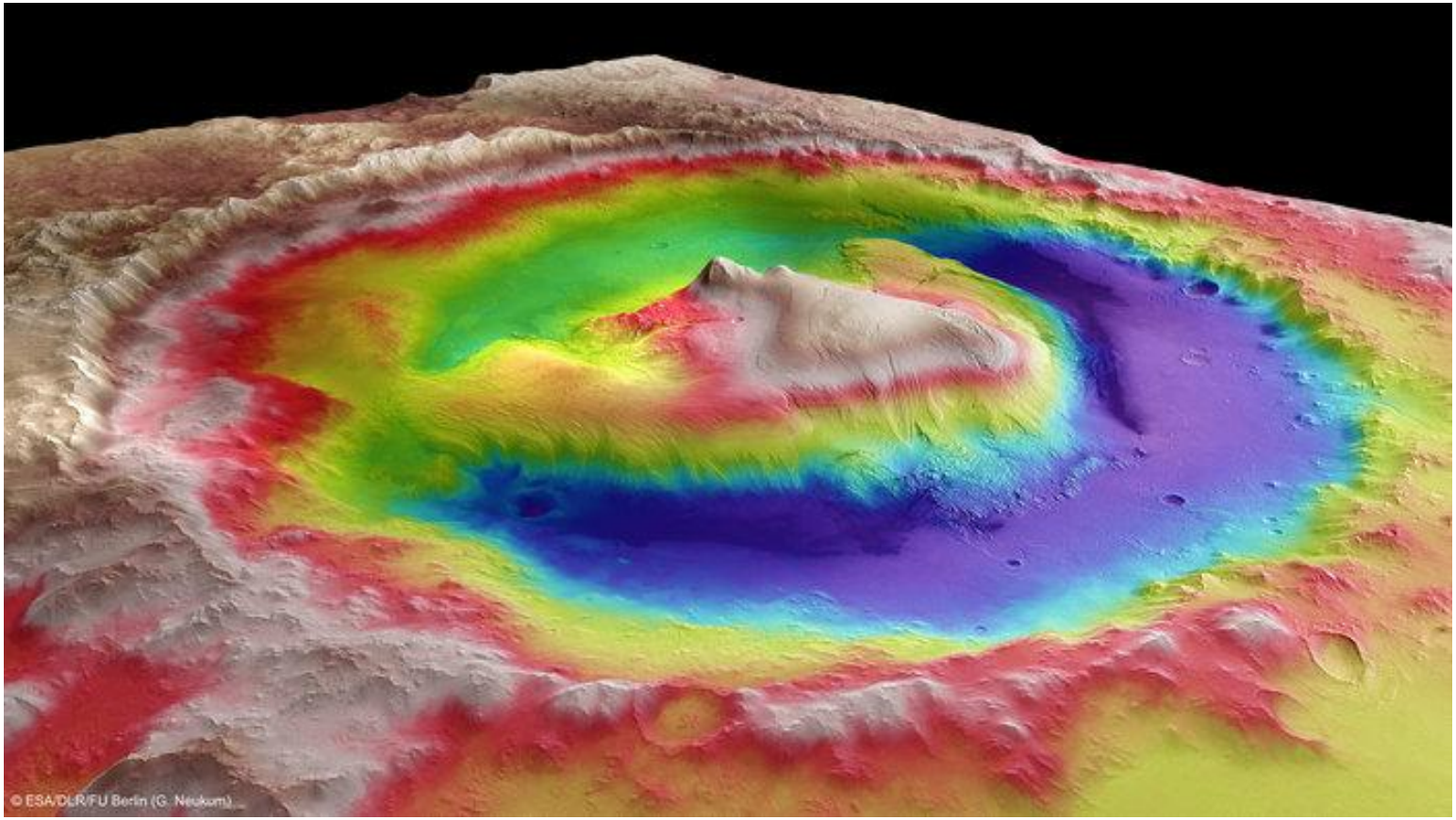


and which is the astrobiological interest of subsurface chemolithotropy?

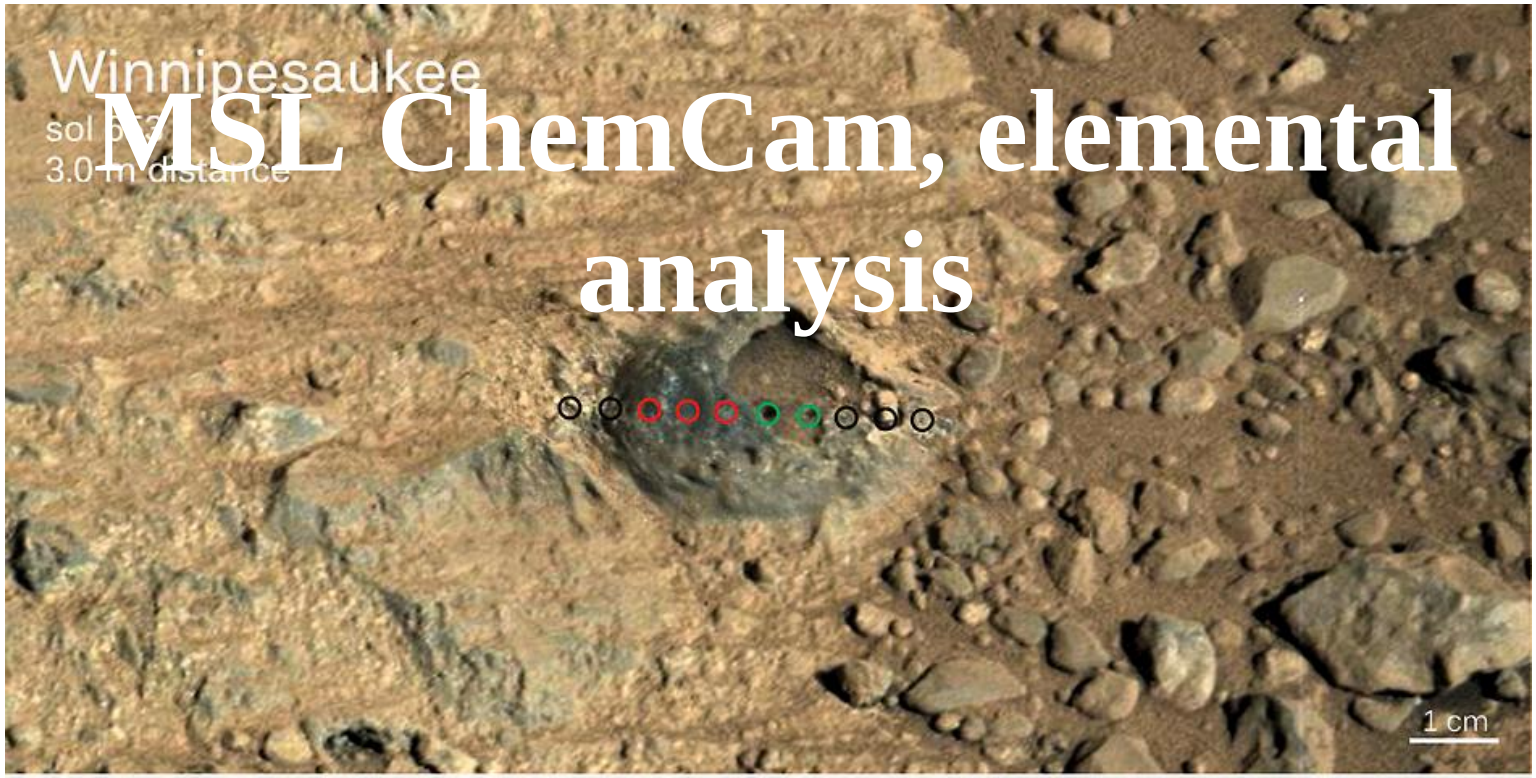
astrobiology

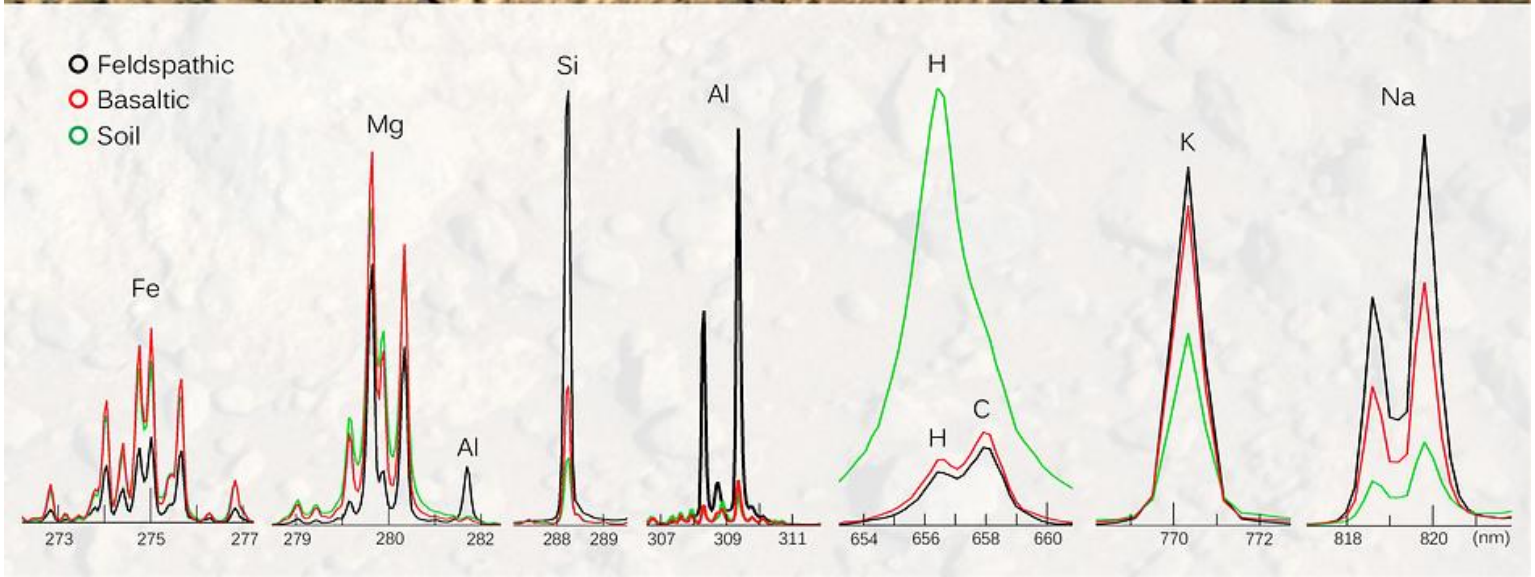


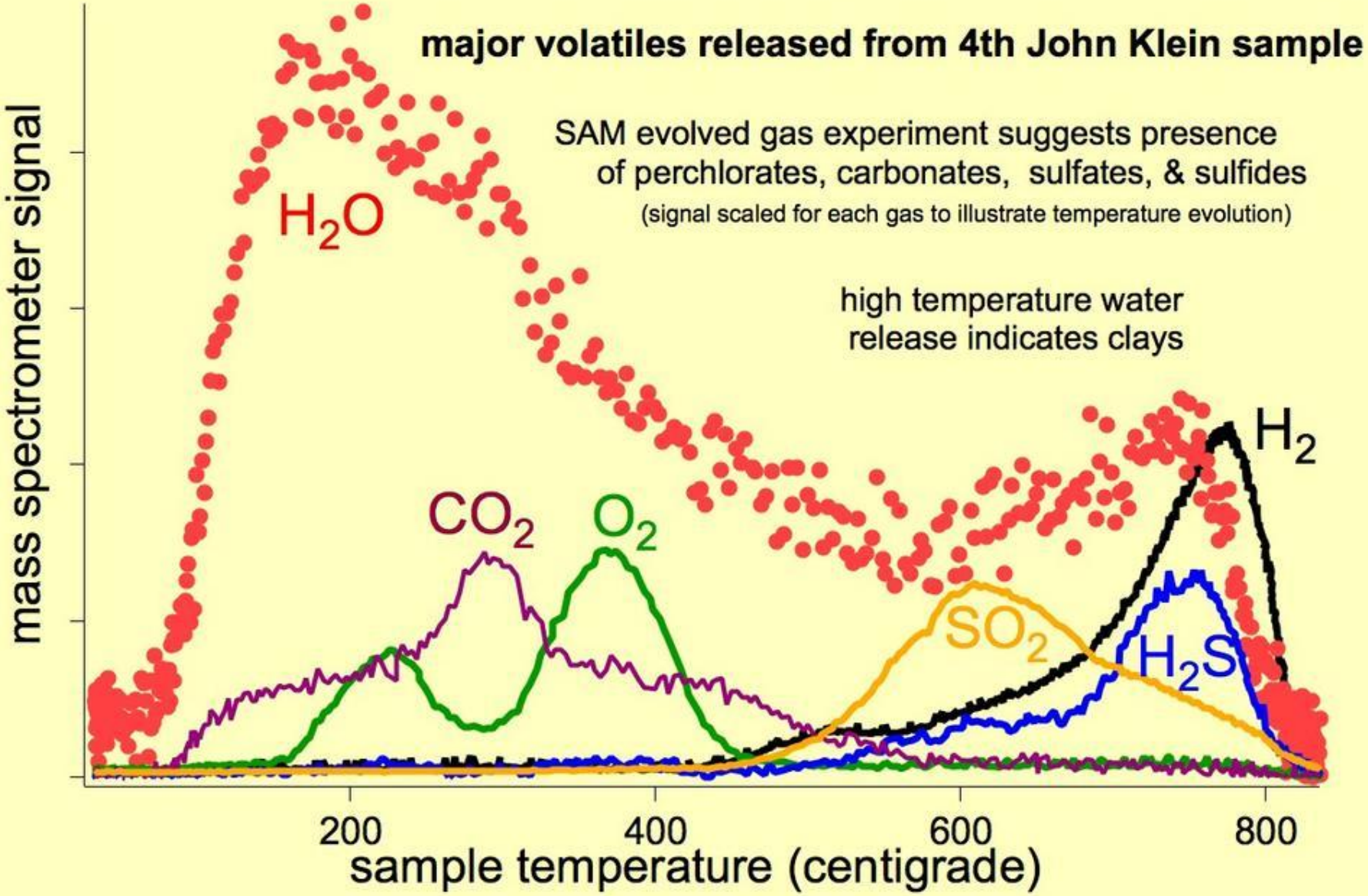
Crater Gale



MSL ChemCam, elemental analysis

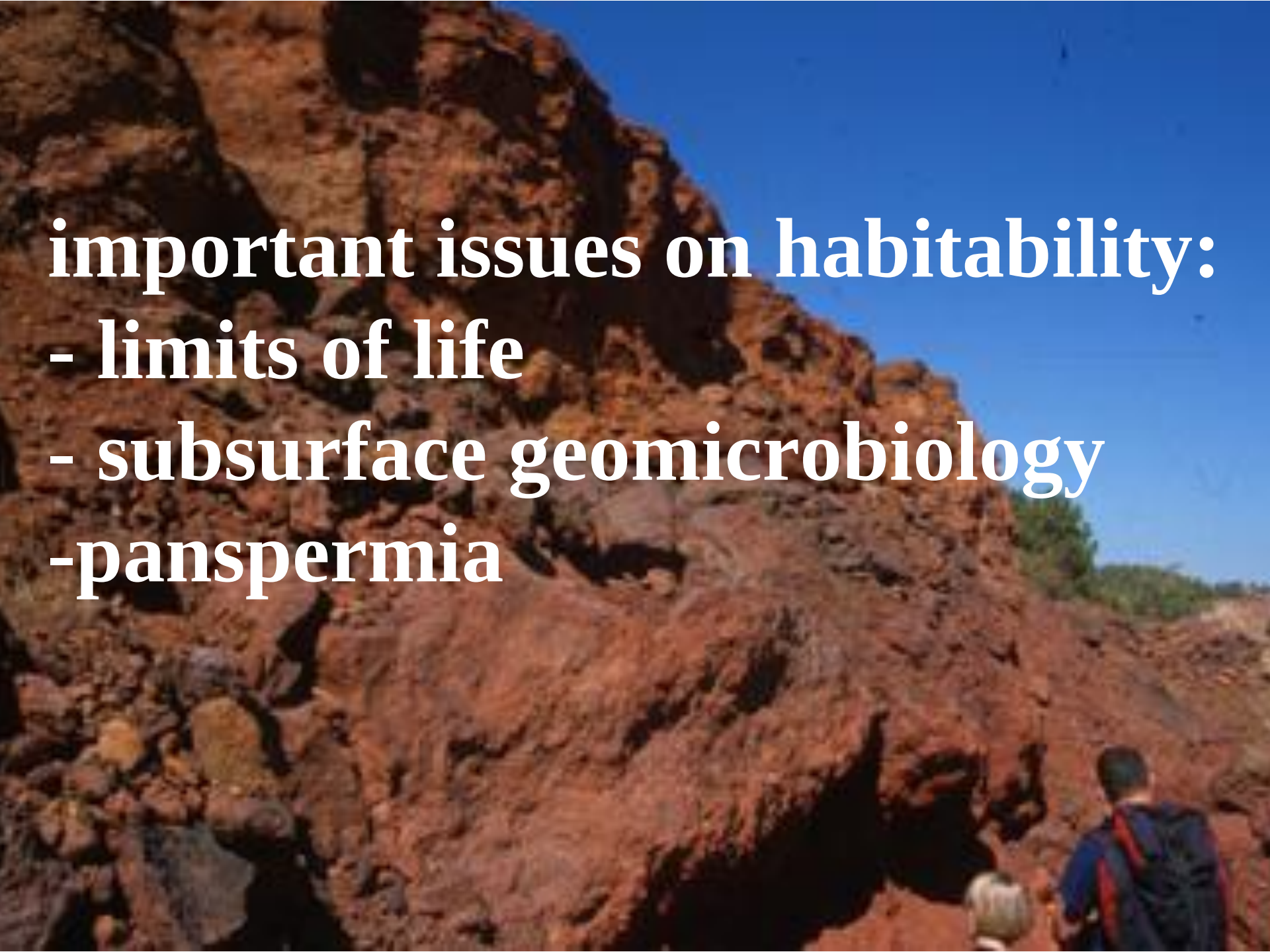





major volatiles released from 4th John Klein sample
SAM evolved gas experiment suggests presence of perchlorates, carbonates, sulfates, & sulfides
(signal scaled for each gas to illustrate temperature evolution)
high temperature water release indicates clays
H_2O
CO_2
O_2
SO_2
H_2S
H_2
mass spectrometer signal
200
400
600
800
sample temperature (centigrade)

LESSONS LEARNED

- underground anaerobic oxidation of Fe^{2+} is quite efficient and responsible of the acidic conditions of Río Tinto.
- compartamentalization (microniches) is extremely important for generating functional biodiversity in anaerobic solid or semisolid matrixes (subsurface, sediments).
- microorganisms can generate microconditions that allow reactions not predicted by global conditions.
- only in situ hibridization and related techniques can help to understand microniche microbial ecology, rest only give global information.
- pay attention to the eukaryotes: fungi, algae.

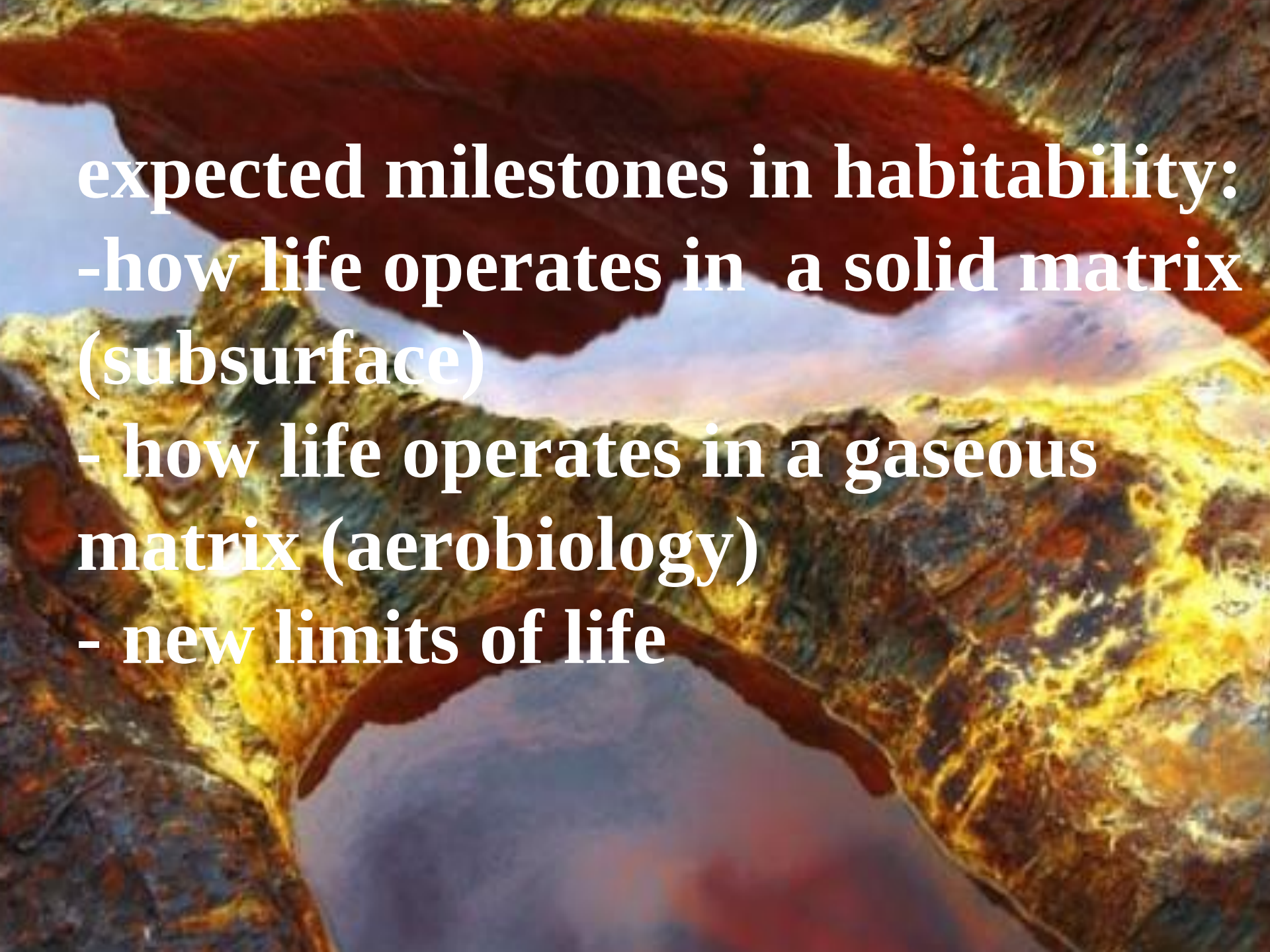


important issues on habitability:

- limits of life

- subsurface geomicrobiology

-panspermia



expected milestones in habitability:

-how life operates in a solid matrix (subsurface)

- how life operates in a gaseous matrix (aerobiology)

- new limits of life

contributions from other fields:

- geology: life-mineral interactions, biominerals

- paleontology: biomarkers

- better knowledge of conditions in exoplanets

- ingineering: design of new instruments


THANK YOU