BACTERIAL ORIGIN OF SELECTED PHANEROZOIC RED CARBONATE ROCKS

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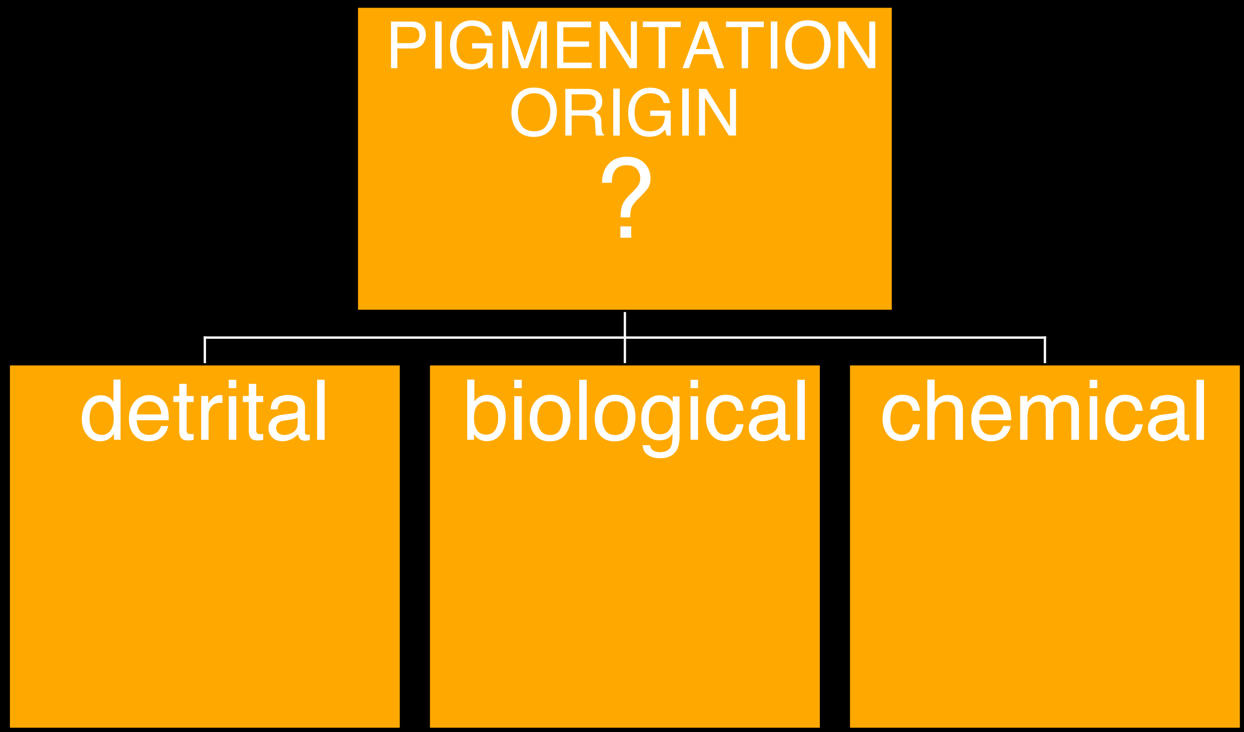
THE PROBLEM…



Red limestones are rare but precious …

- griottes Devonian S-France, Viséan N-Spain
- 'red marbles' Devonian (Frasnian), Belgium
- Ammonitico Rosso Jurassic, N-Italy, S-Spain
- ' red marble' Devonian, Czech Republic
- red condensed series Devonian, Morocco
- red lenses in slope Carboniferous, N-Spain

cathedrals, castles, Versailles, Trianon…

… how can we explain the red colour that made the stone so scarce?

XVIIIth-XIXth centuries : red = iron (Delhaye, 1908)

- the iron is detrital (Reijers, 1985), transported from the continent, then mixed with the carbonate matrix during sedimentation …
- its concentration and degree of oxidation produce colour variations (reddish)

LATER ON (1964-1988)

a relation between ferruginization/palaeogeography/climate is the fashion : washed equatorial laterite soils provide great quantities of iron oxides… thus the red limestones are used as palaeoclimatic indicators!

oxygenation degree ?
(in non clastic rocks)

- red limestones are found in oxidized facies
- green limestones indicate reducing conditions

both indicate shallow waters

red silicified limestones (lydites)
indicate deep environments
with minimum amounts of iron and oxygen !
… but they are not reduced…

basic observations …

the Fe content of red limestones
of biotic origin is comparatively low

↓

1 to 2 %, often < 1 %

…therefore this content is not responsible
of the coloration

There is no direct relation between oxygen content and overall iron oxidation...

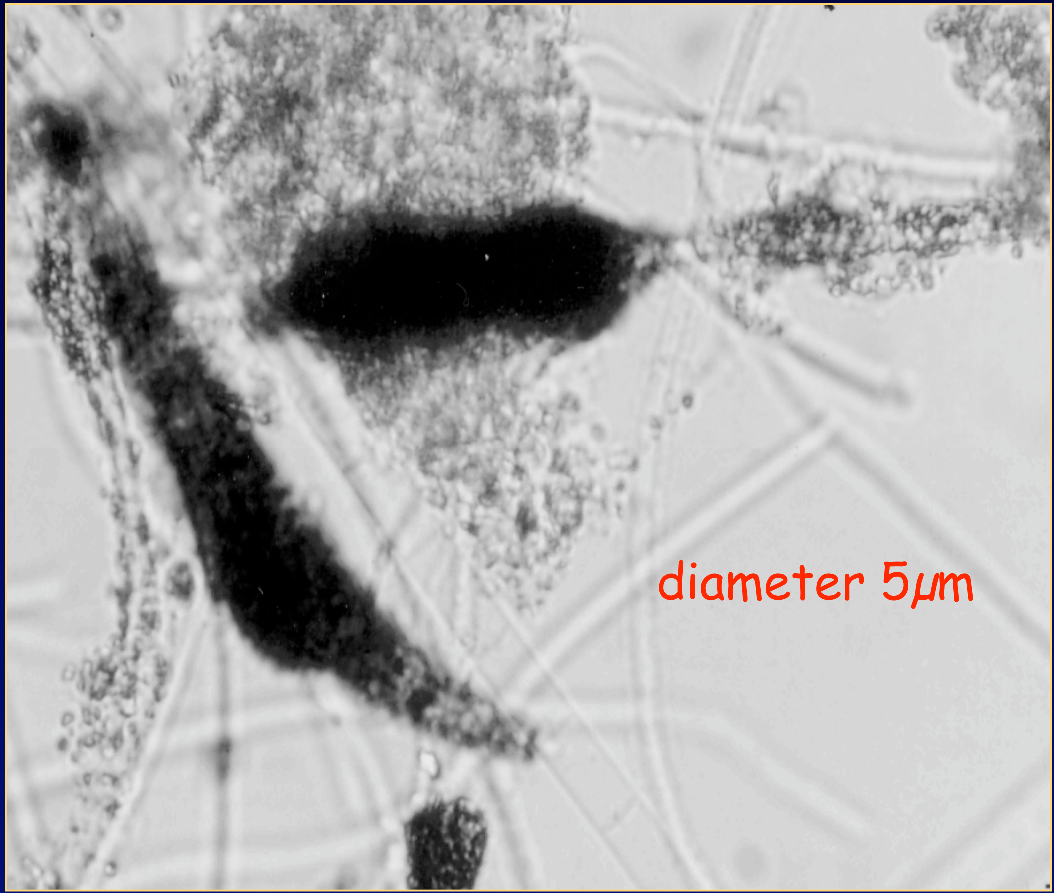
Thus the colour is not necessarily linked to shallow water marine environments where oxygen is abundant

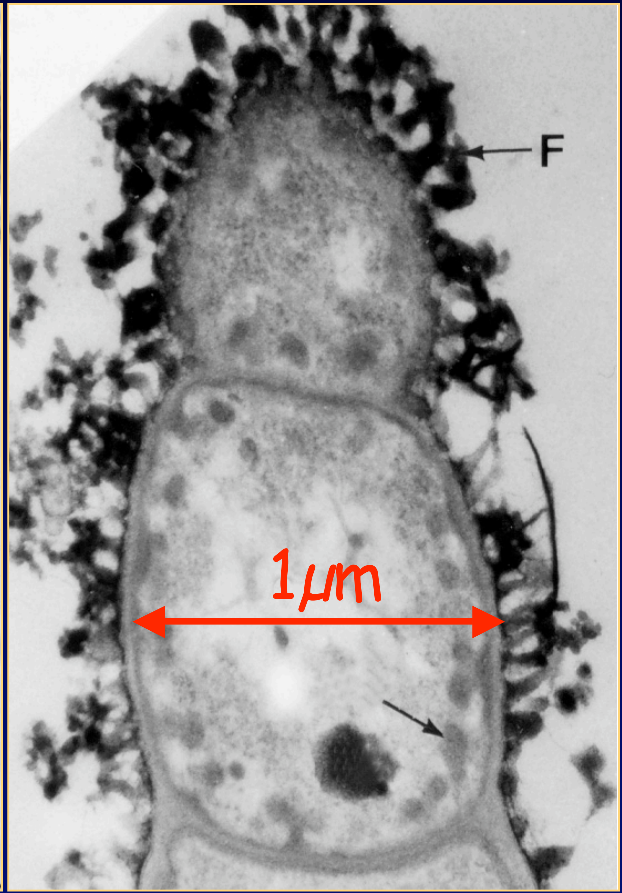
QUID ?

sedimentation is in a NORMAL OPEN MARINE facies

red limestones are formed in calm environments, with low levels of oxygen

in the RECENT…



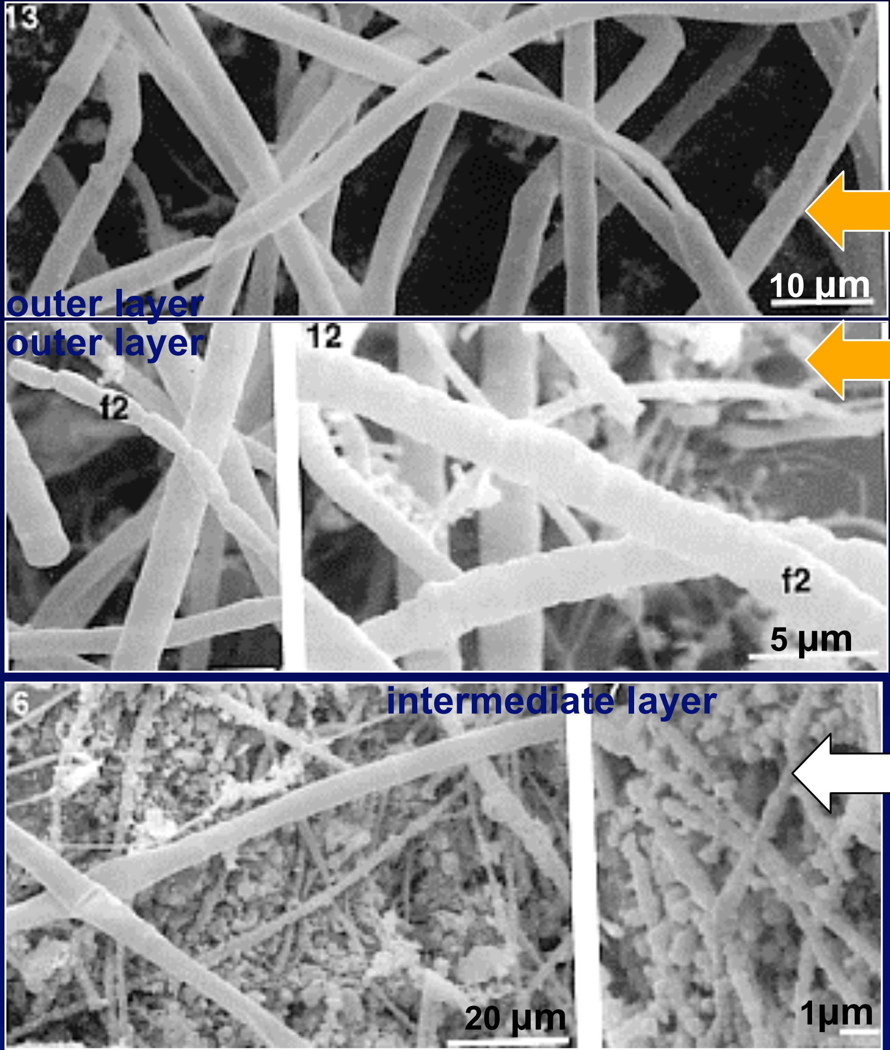


Gillan 2003

Iron bacterial filaments
on a shell
(photonic microscopy)

Filamentous iron bacteria
(TEM)
F = Fe

Montacuta ferruginosa

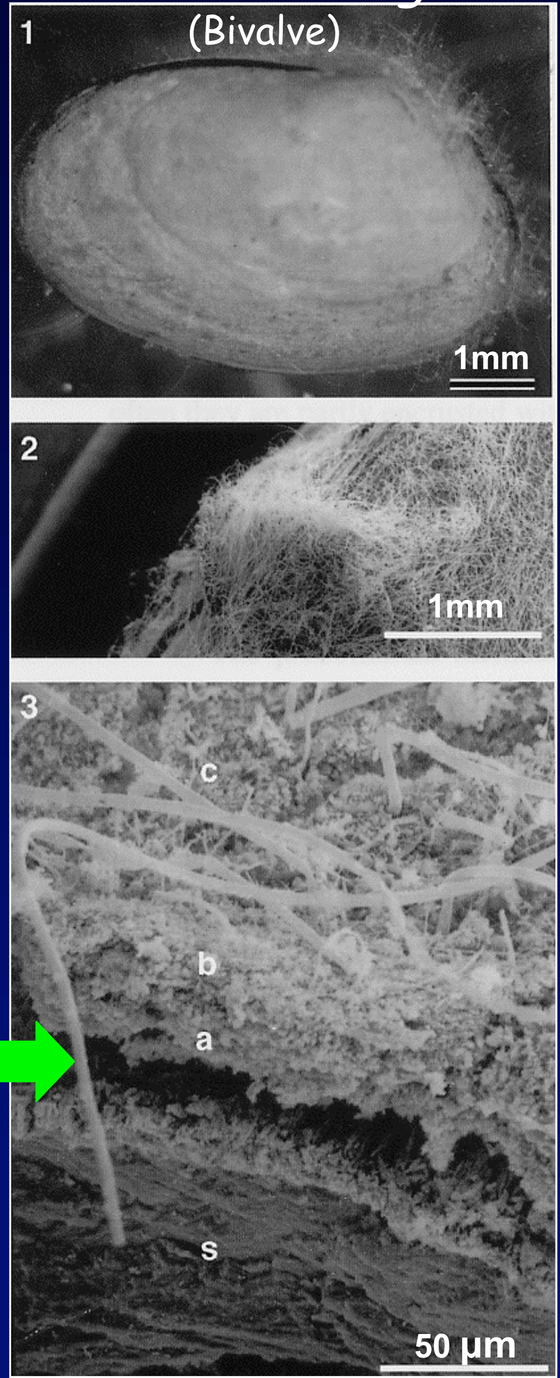


intermediate layer

Outer layer
= bacteria
non incrusted
poorly or
with
Fe deposits

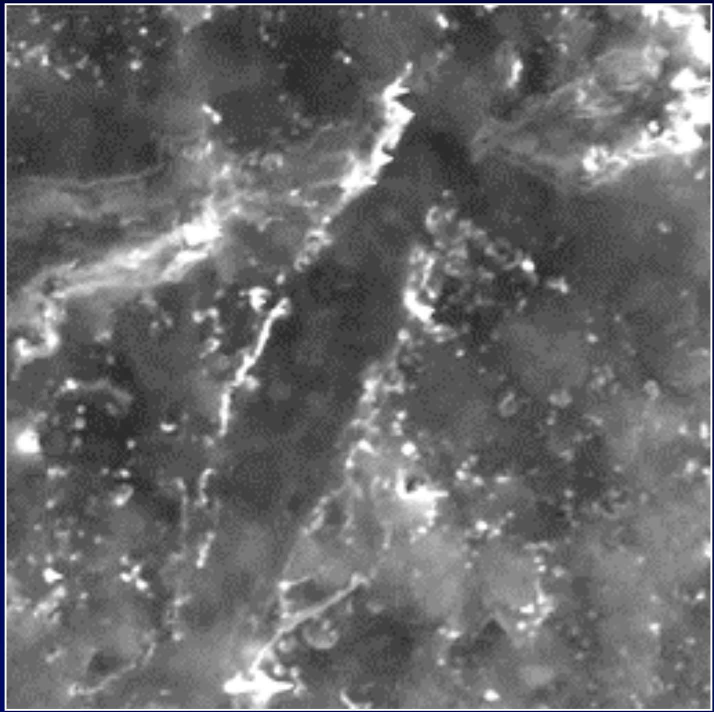
Intermediate
= bacteria
heavily incrusted
with
Fe deposits

Inner
=
ferric iron deposits



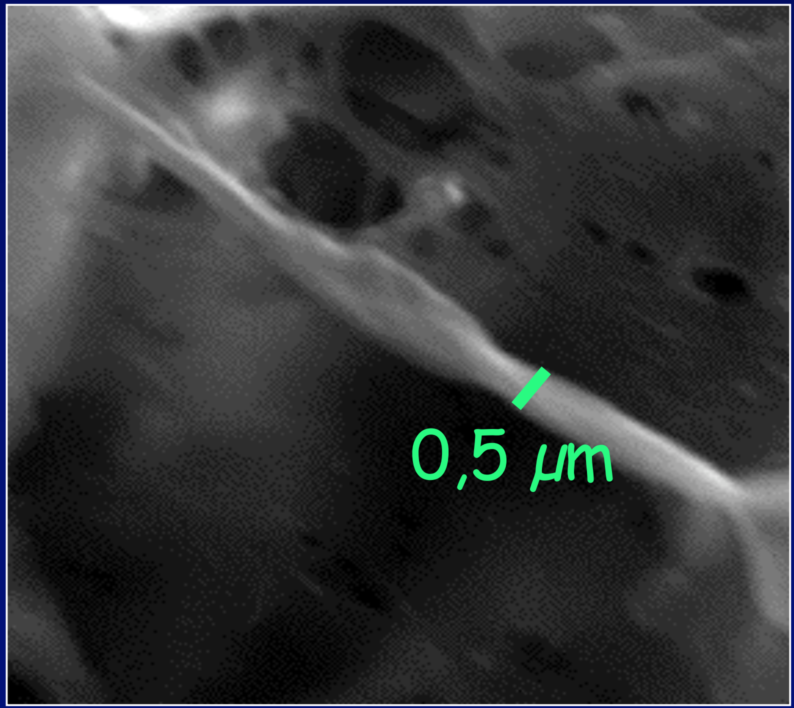
Gillan 2001

more Recent examples

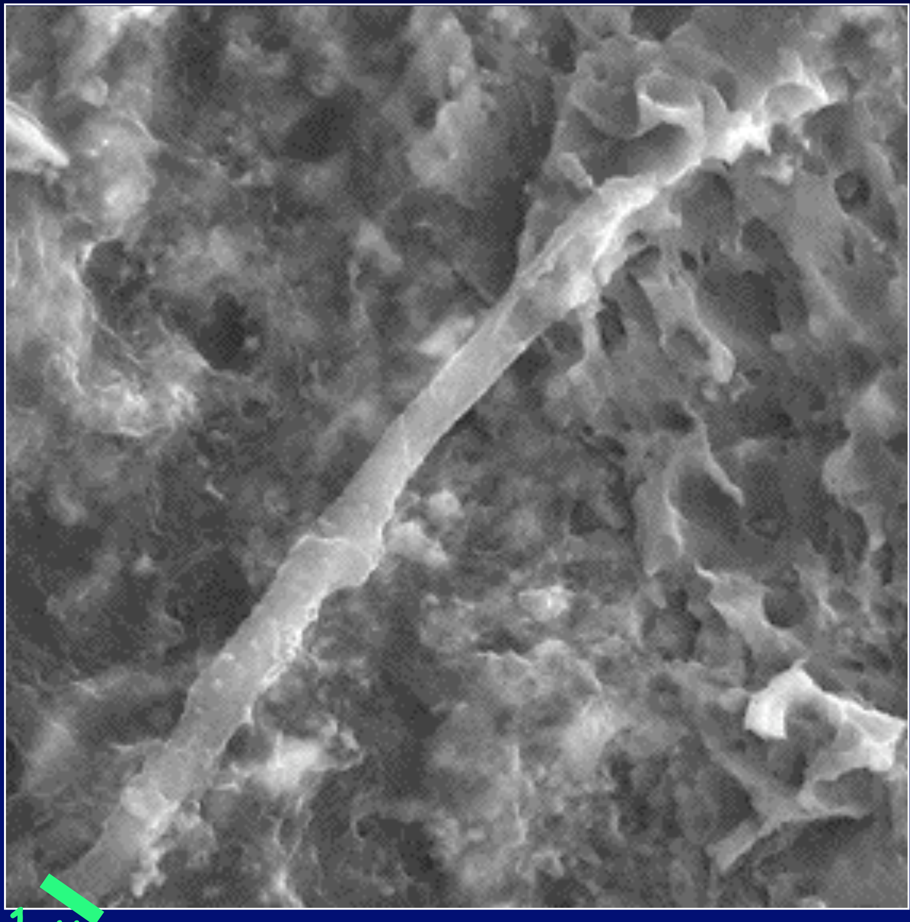


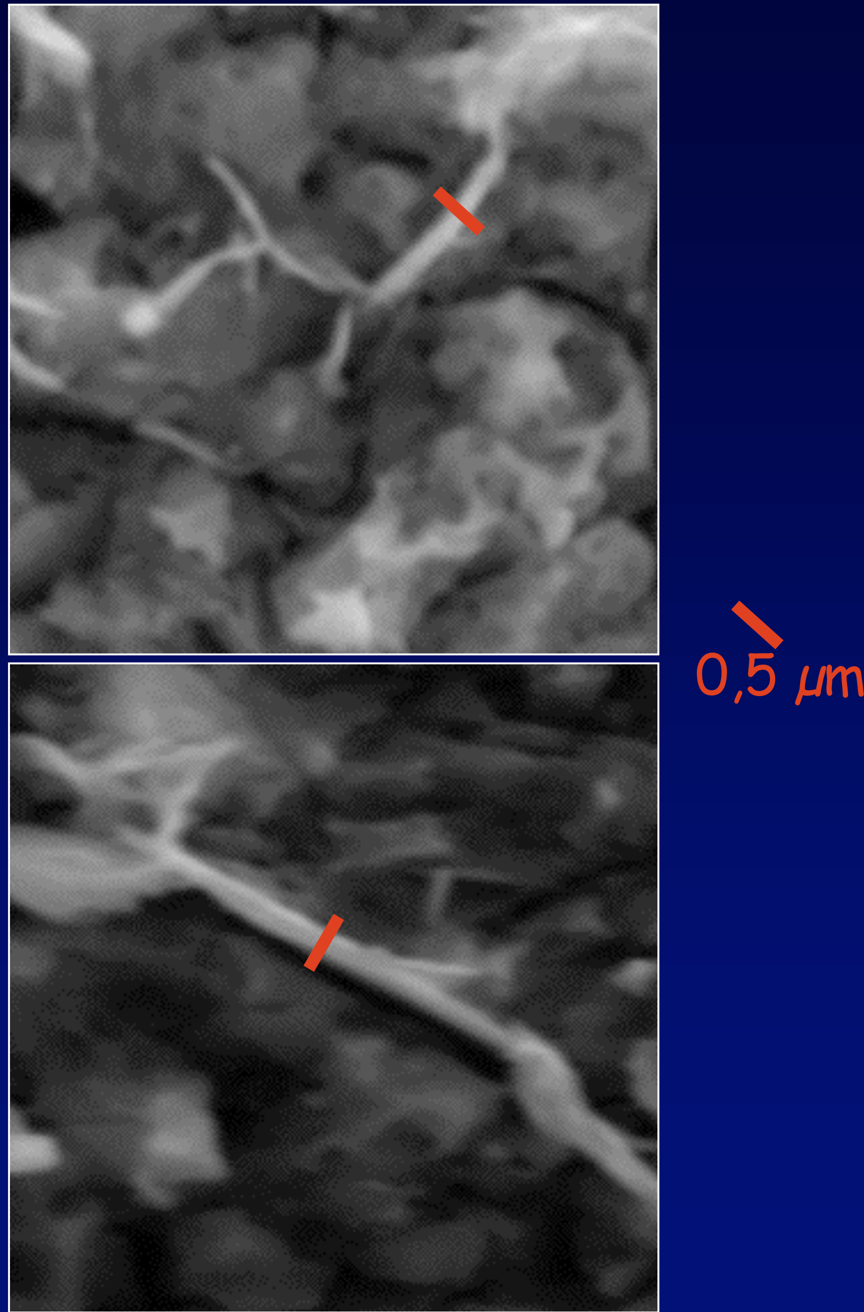
In the Phanerozoic

inframicrometric
hematite
crystals coating
bacterial
filaments



Italian
Ammonitico Rosso
Jurassic





Italian
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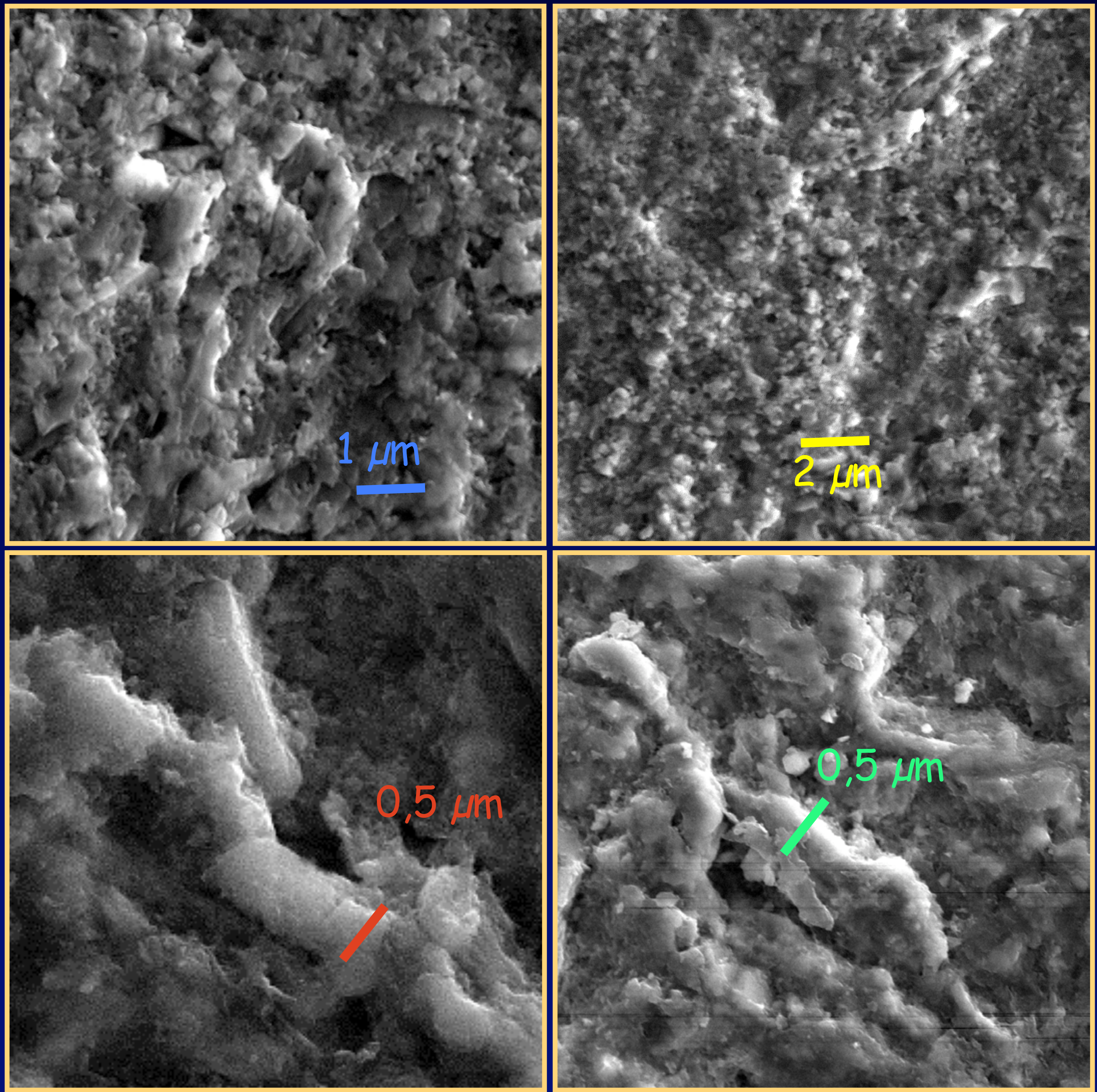
Italian Ammonitico Rosso Jurassic

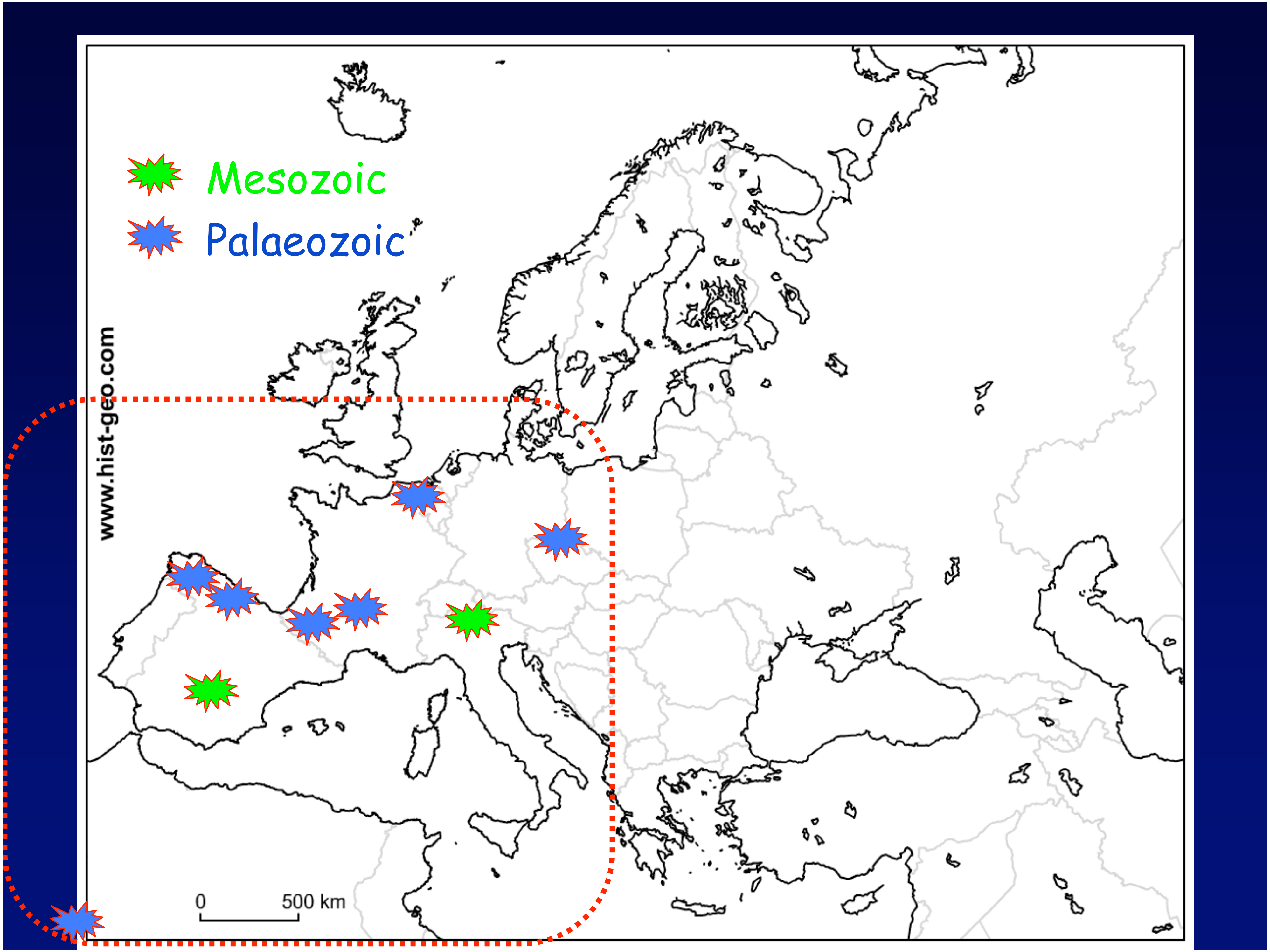


benthic bacterial mats up to 20%

Microscopic morphologies of the iron constructions

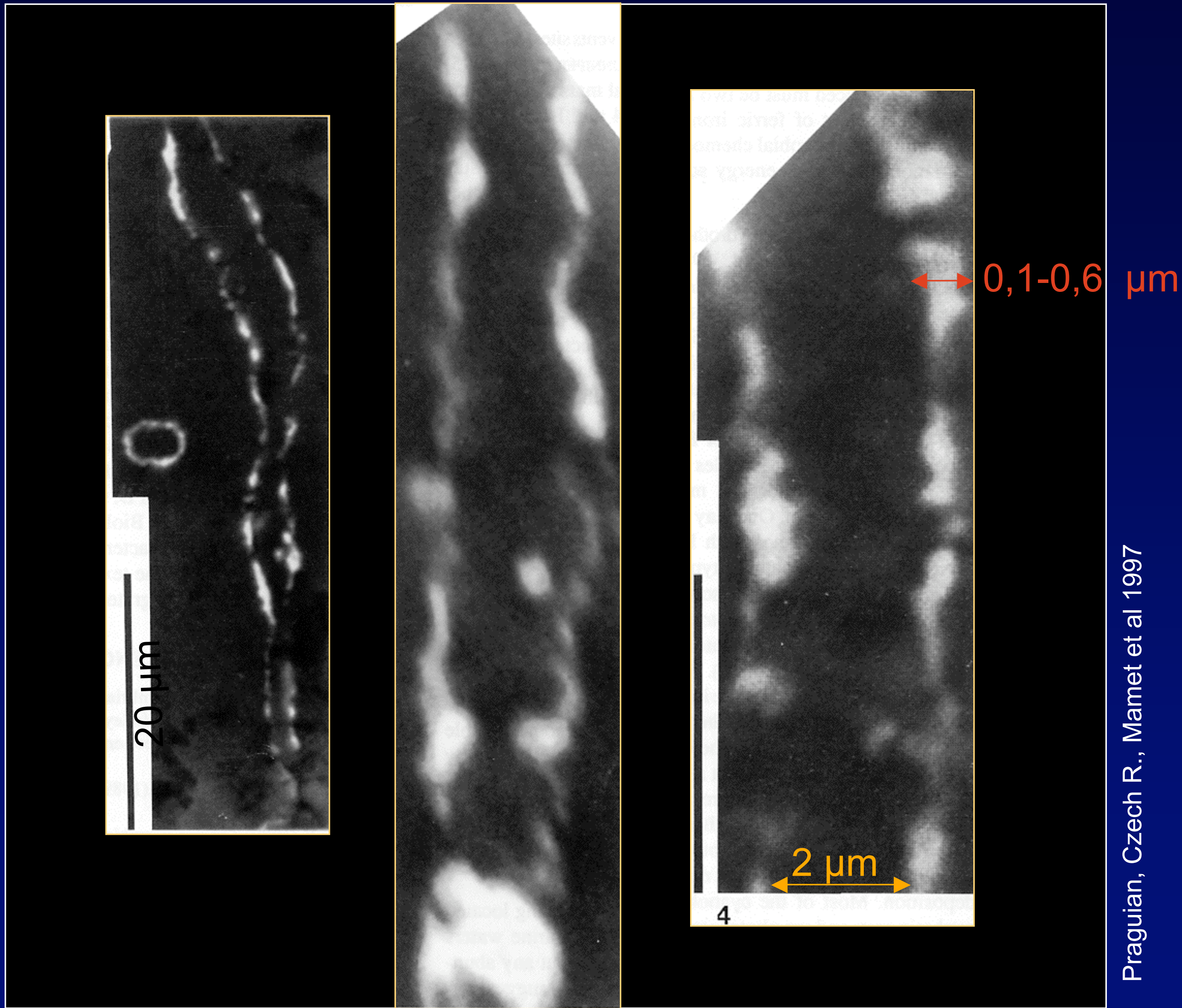
- infillings of original fossil cavities
- calcite replacement of dissolved echinoderm plates
- infillings of bioperforations
- bacterial/fungal filaments
- ‘hedgehogs’ and ‘erythrospheres’
- massive hematite coating around microfossils
- simple or multiple biofilms
- microstromatolites (exogens ou endogens, crenulated or not...)
- oncolites

….. non exhaustive ….


Mesozoic
Palaeozoic
www.hist-geo.com
0
500 km

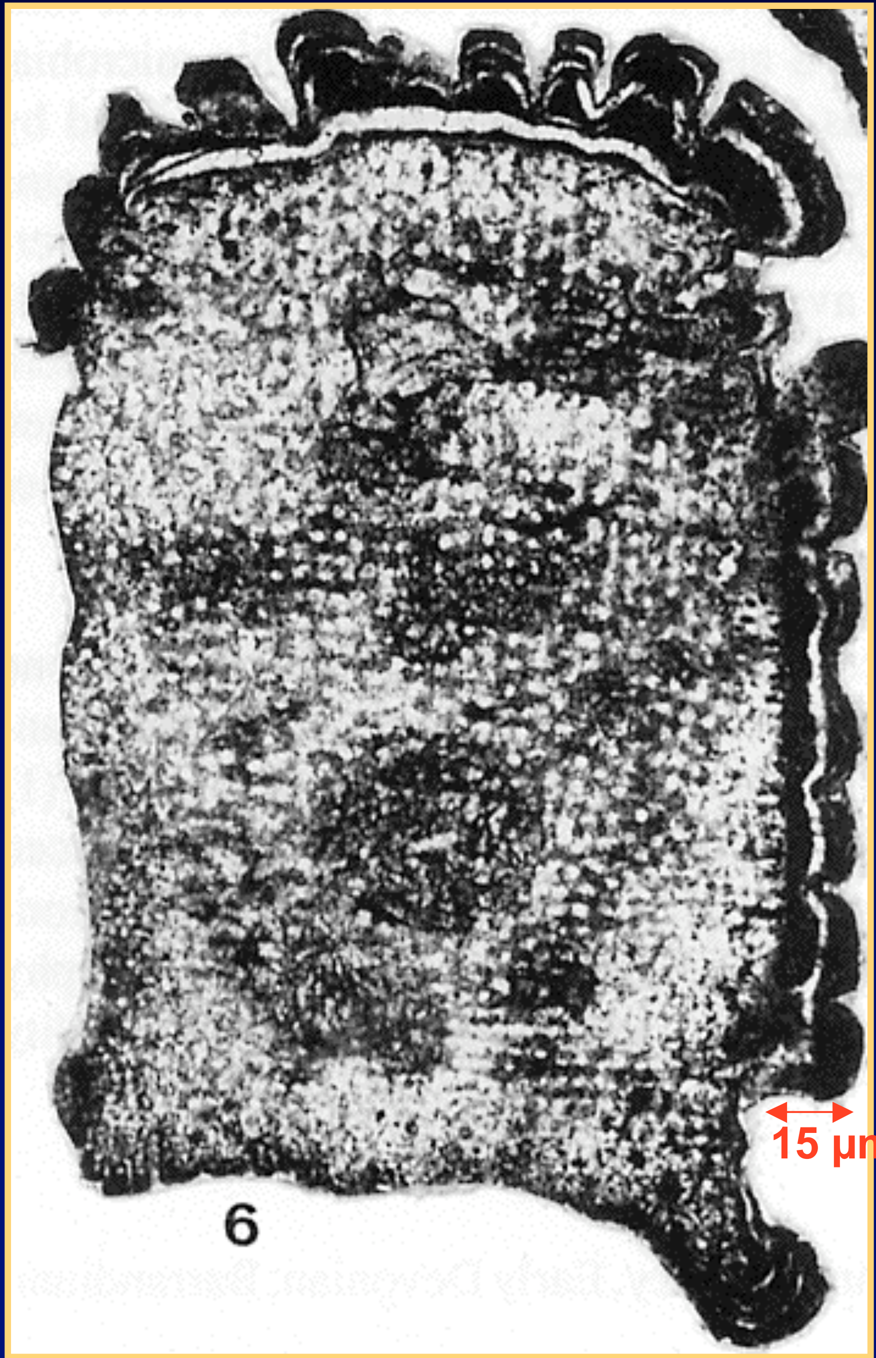
OBSERVED MICROFACIES OF DIFFERENT AGES AND LOCALITIES

CZECH REPUBLIC, LOWER DEVONIAN



Praguian, Czech R., Mamet et al 1997

CZECH REPUBLIC, LOWER DEVONIAN

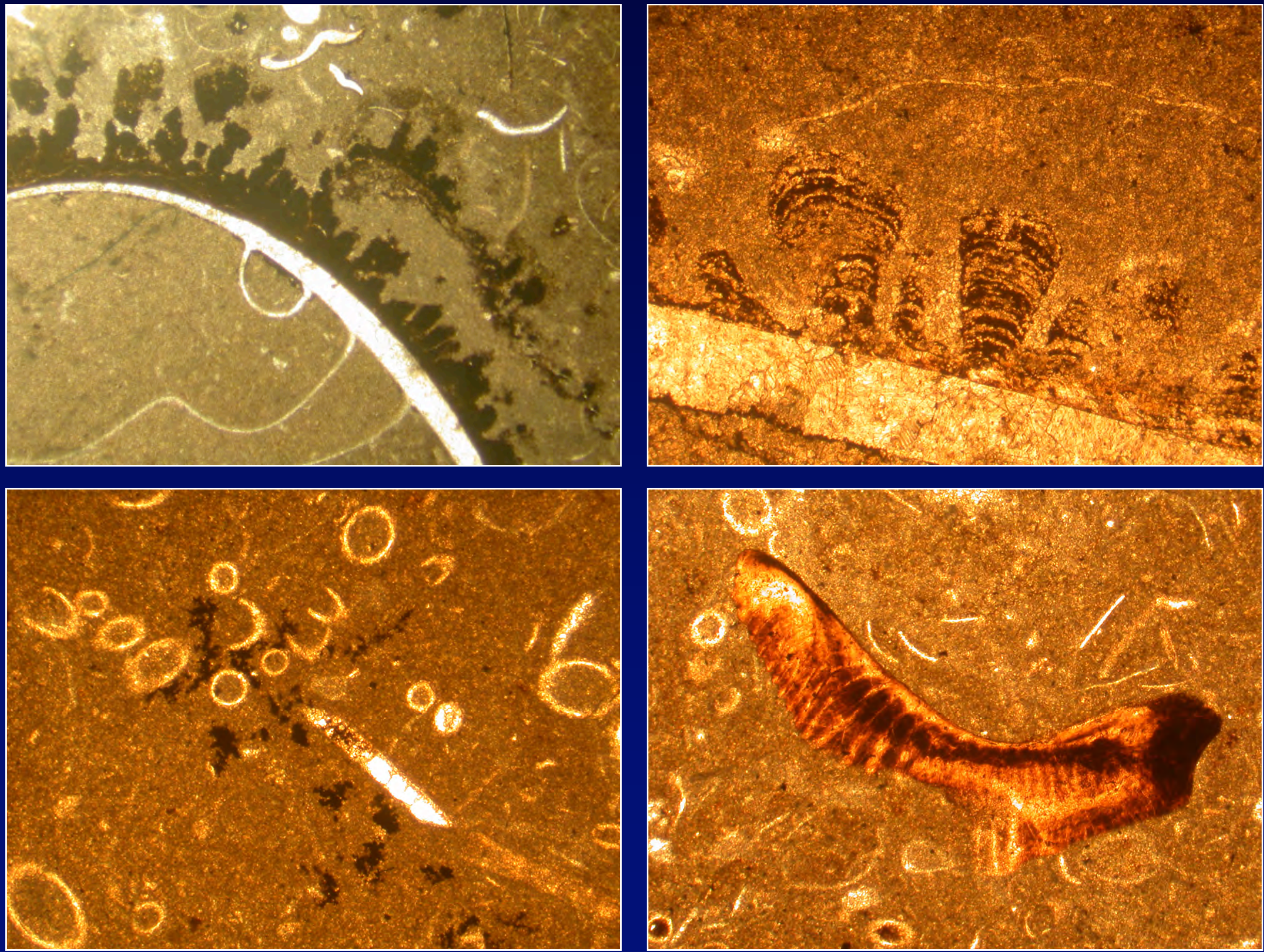


Praguian, Czech R,Mamet et al 1997

Asymmetrical growth of Fe-stromatolites on two sides of an altered echinodermal plate

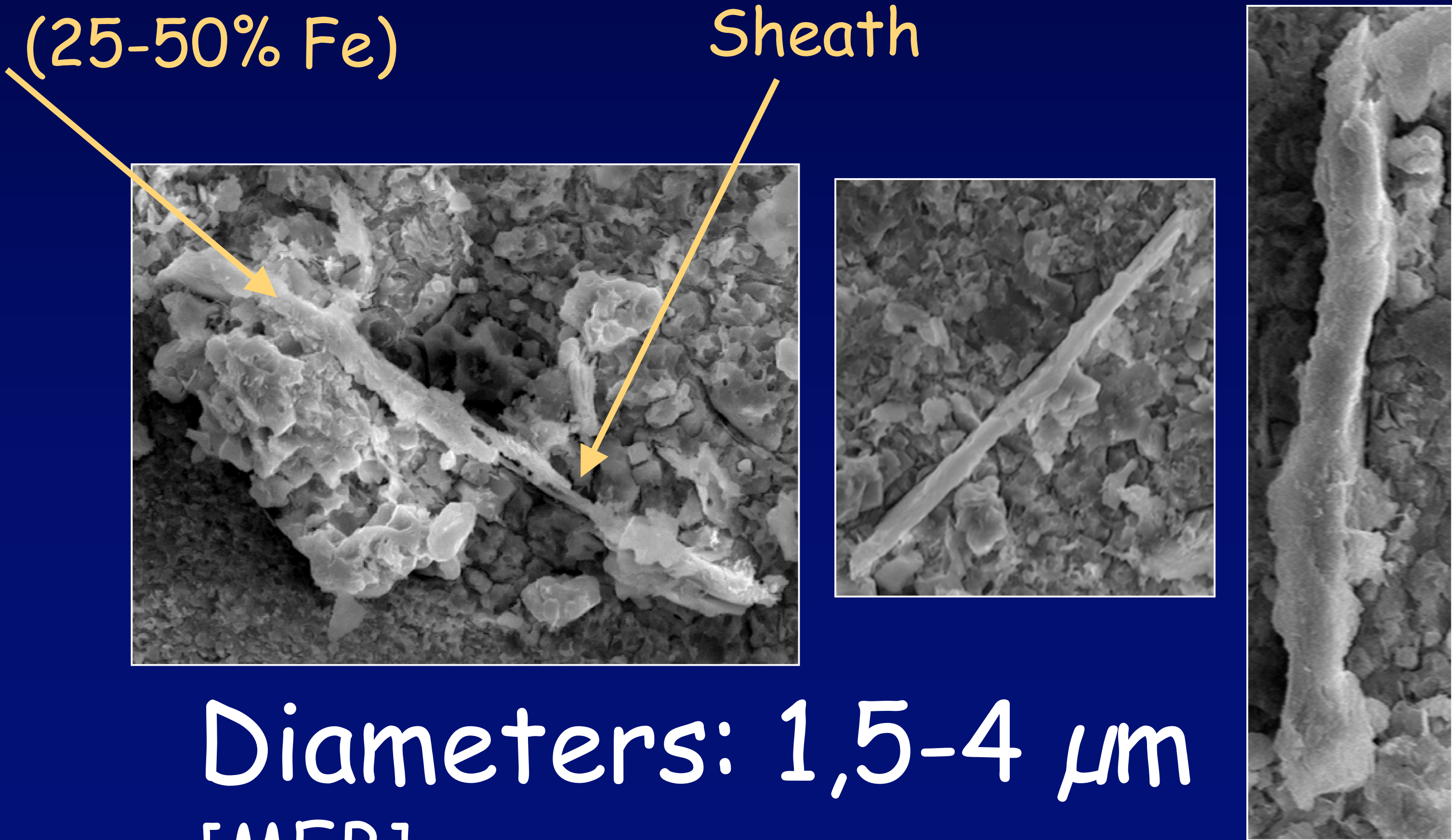
The two other sides are devoid of coating

ANTI-ATLAS, MOROCCO LOWER-UPPER DEVONIAN



ANTI-ATLAS, MOROCCO LOWER-UPPER DEVONIAN

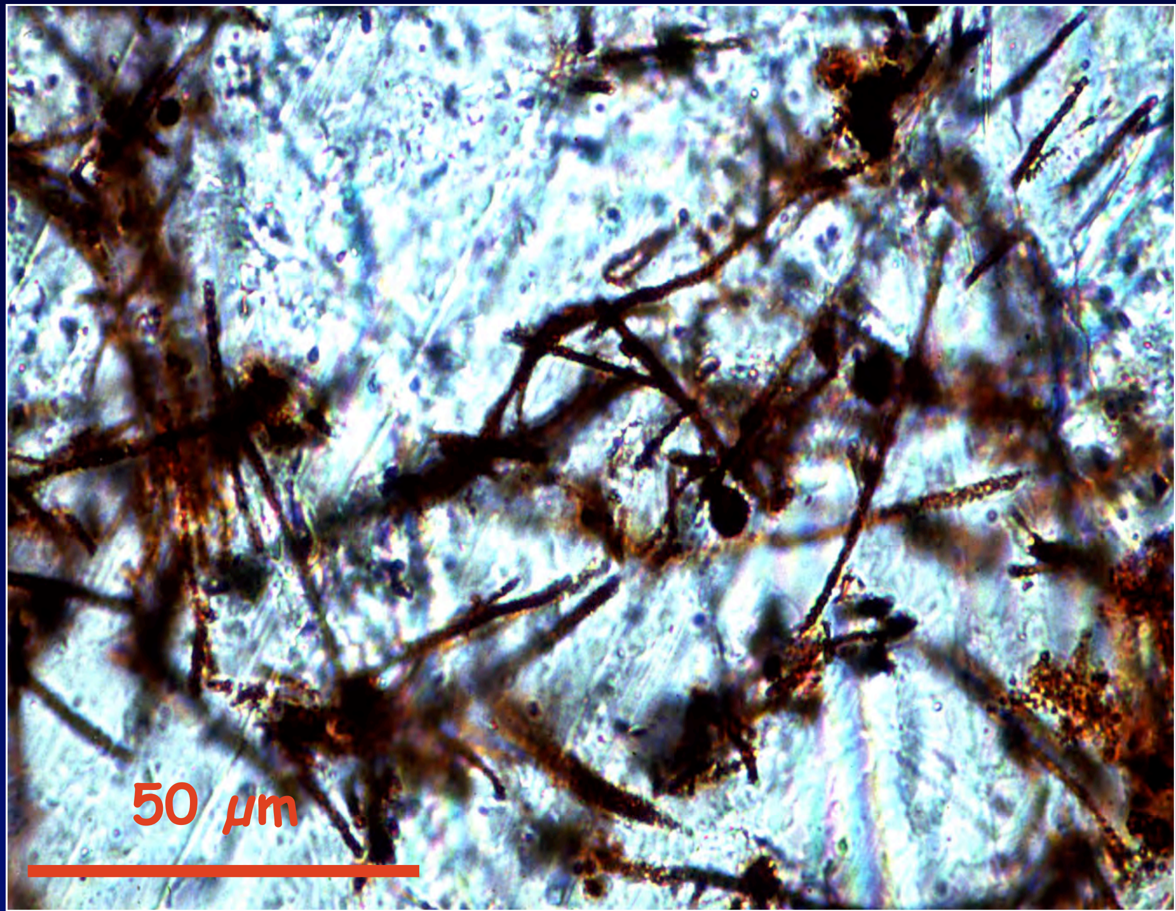
Filamentous iron bacteria



Diameters: 1,5-4 μm

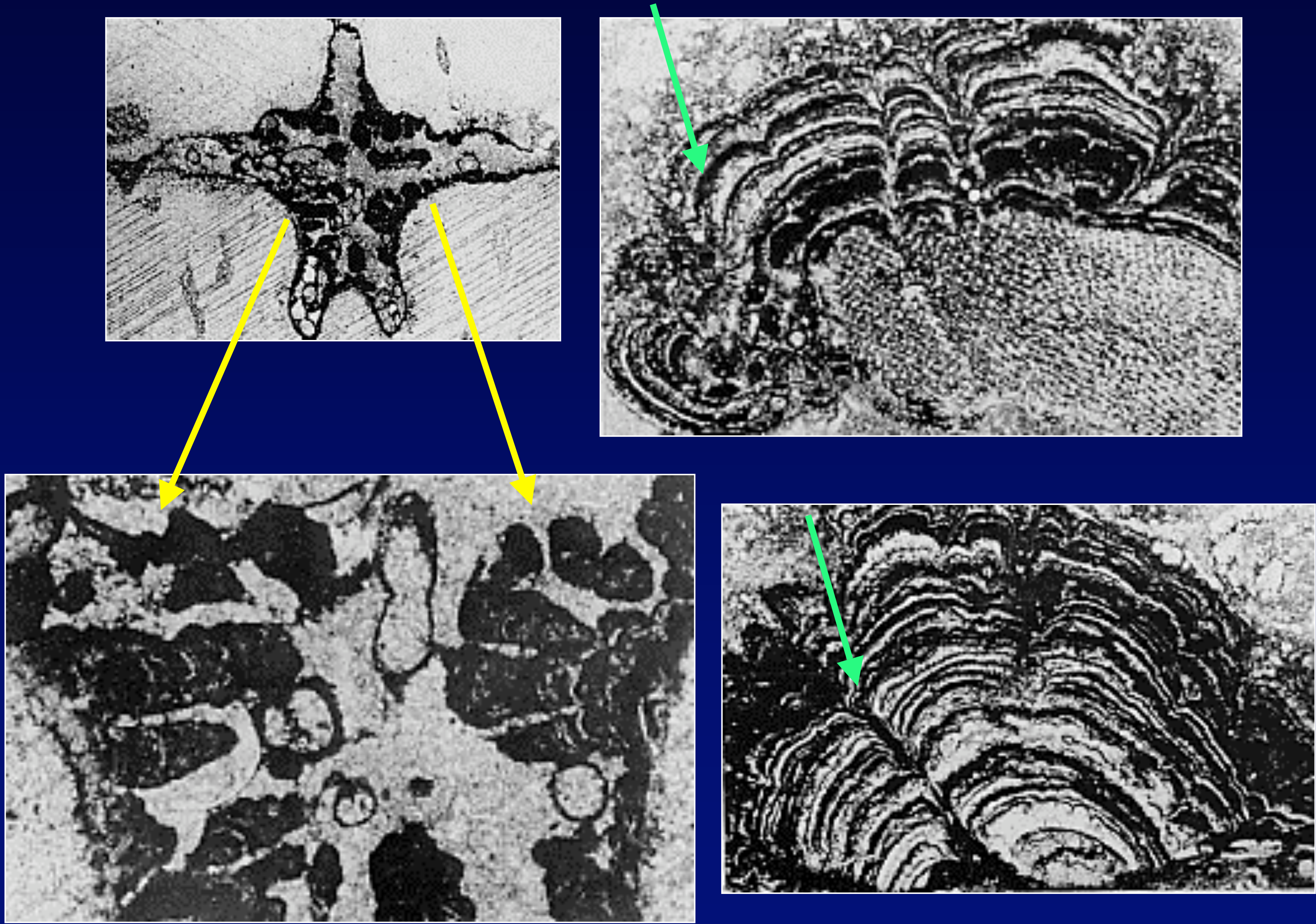
[MEB]

FRENCH-BELGIAN MUD MONDS, FRASNIAN



Iron-bacteria
(*Siderocapsa*-like, *Sphaerotilus-Leptothrix*-like
in the internal sediments of *Receptaculites*
Rochefontaine quarry, Franchimont, Philippeville
Massif (Boulvain et al. 2001)

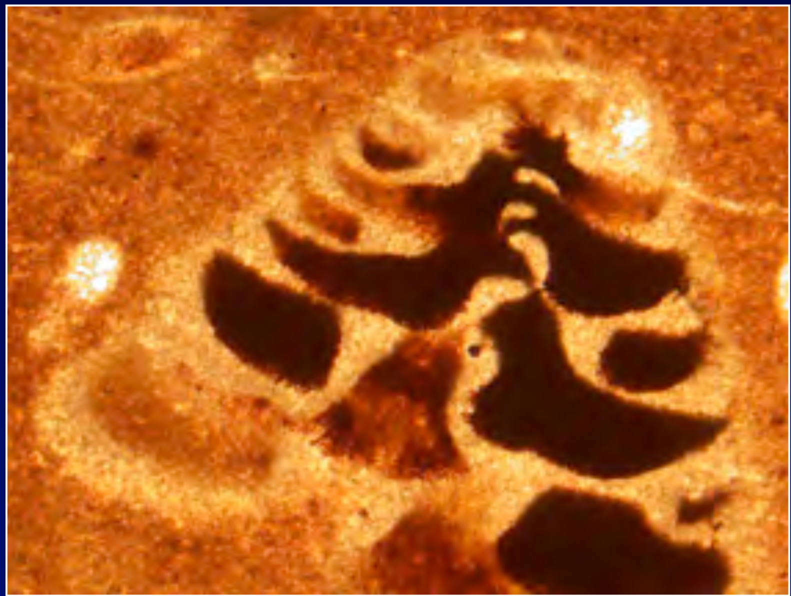
BALEAS GRIOTTES, SPAIN, CARBONIFEROUS

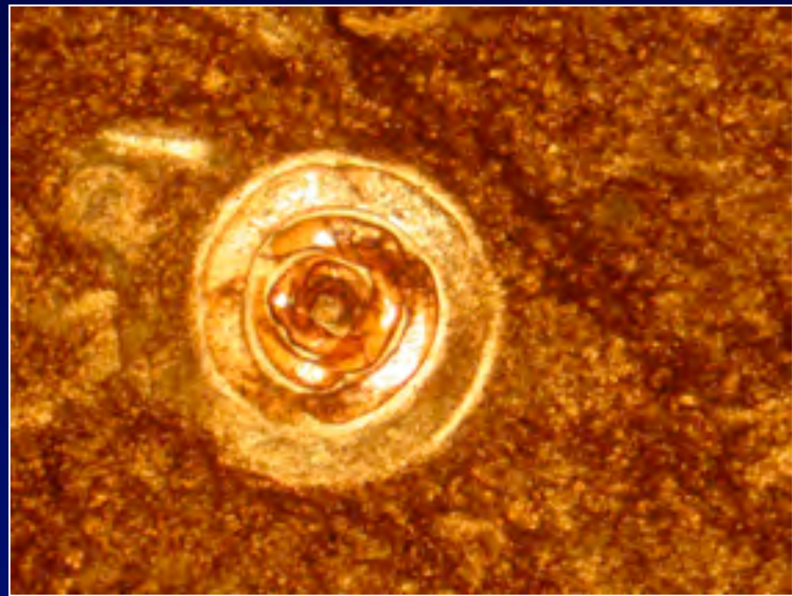


with endostromatolites and microstromatolites

SIERRA DEL CUERA, SPAIN, CARBONIFEROUS

Infillings of original fossil cavities, biofilms

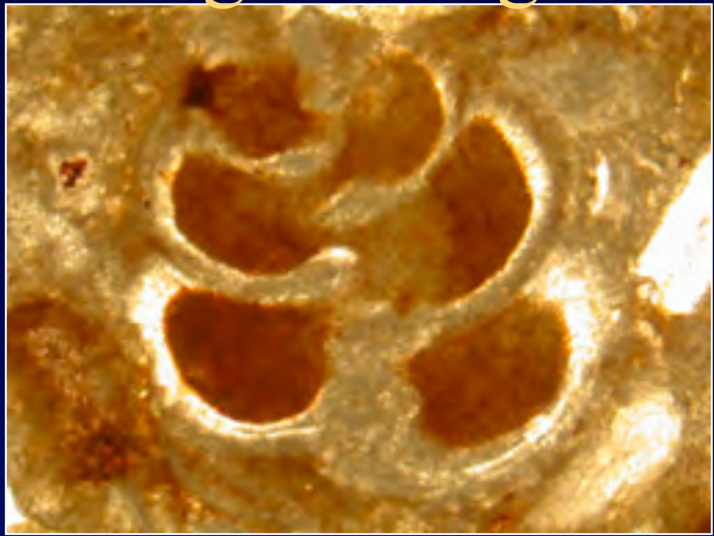


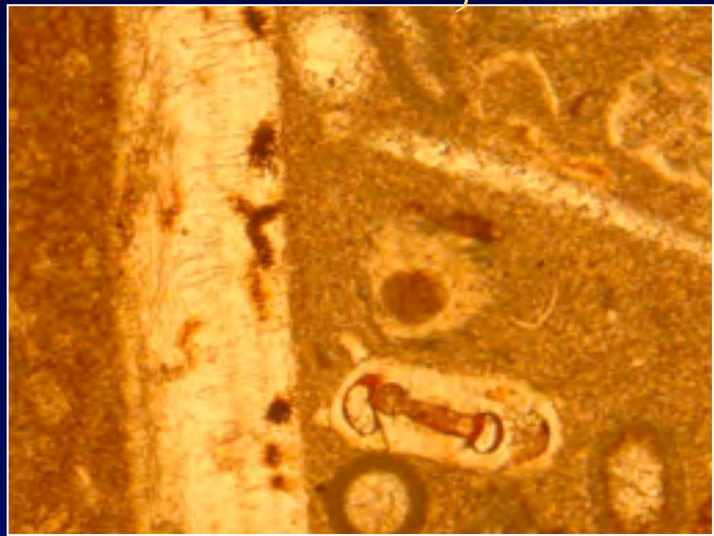


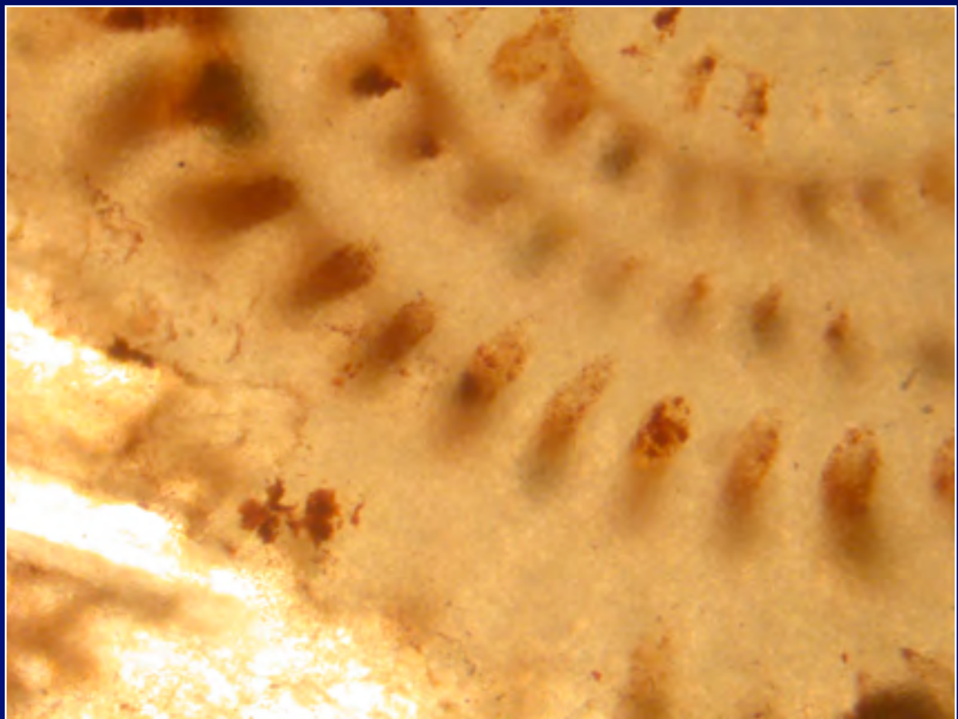
also bryozoan, gastropods, ostracods, tentaculids ...

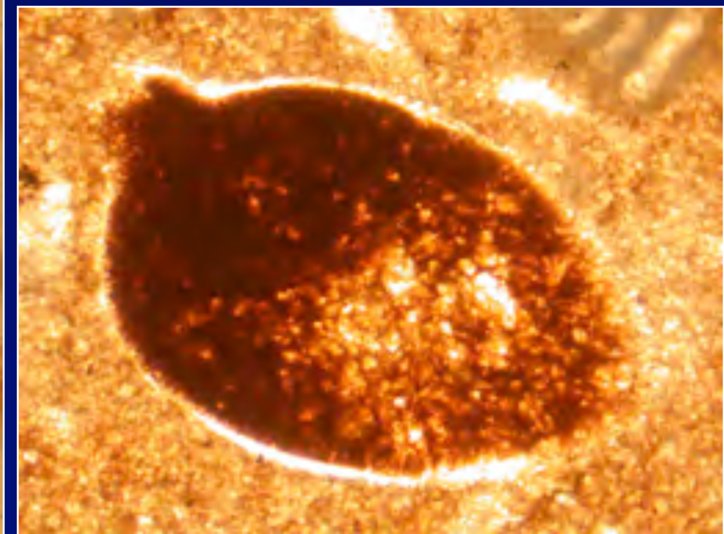
SIERRA DEL CUERA, SPAIN, CARBONIFEROUS

Infillings of original fossil cavities, biofilms









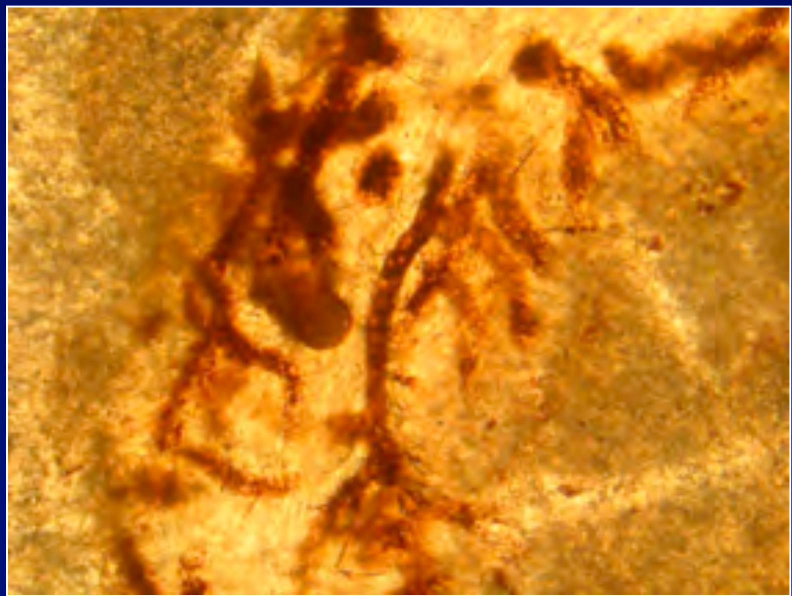
SIERRA DEL CUERA, SPAIN, CARBONIFEROUS

Infillings of bioperforations

Brachiopods, Pelecypods, Bryozoans, Foraminifers

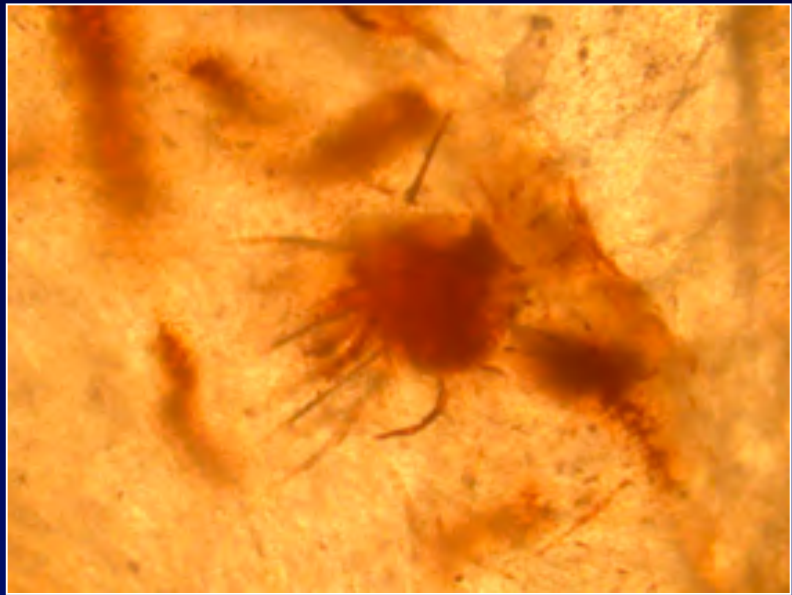
SIERRA DEL CUERA, SPAIN, CARBONIFEROUS

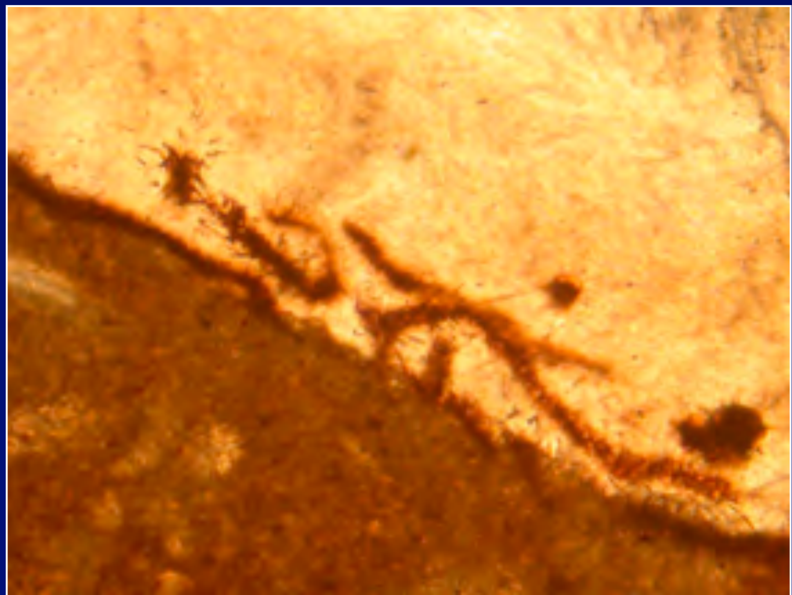
Infillings of bioperforations and filaments ('cactus')



SIERRA DEL CUERA, SPAIN, CARBONIFEROUS

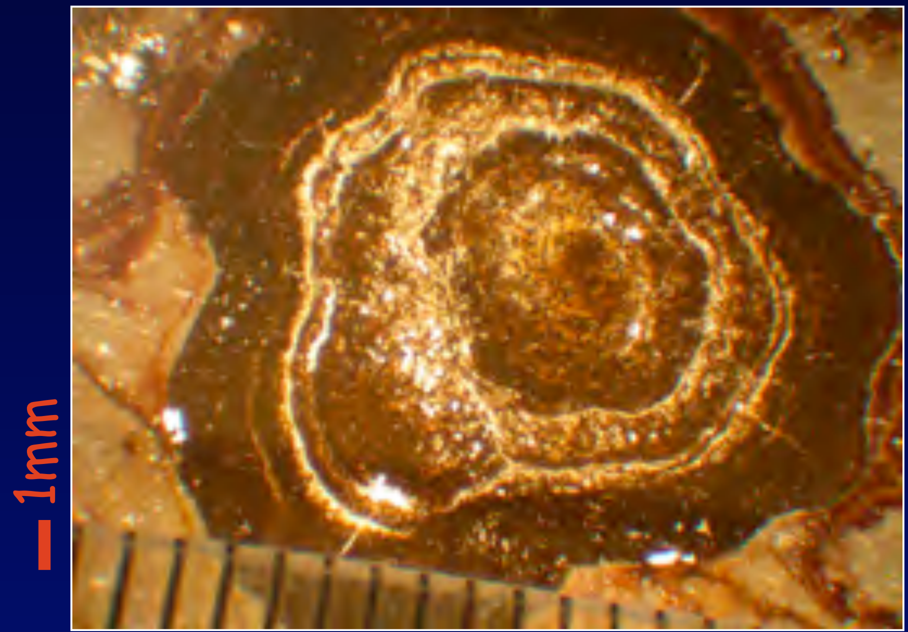
‘Erythrospheres’

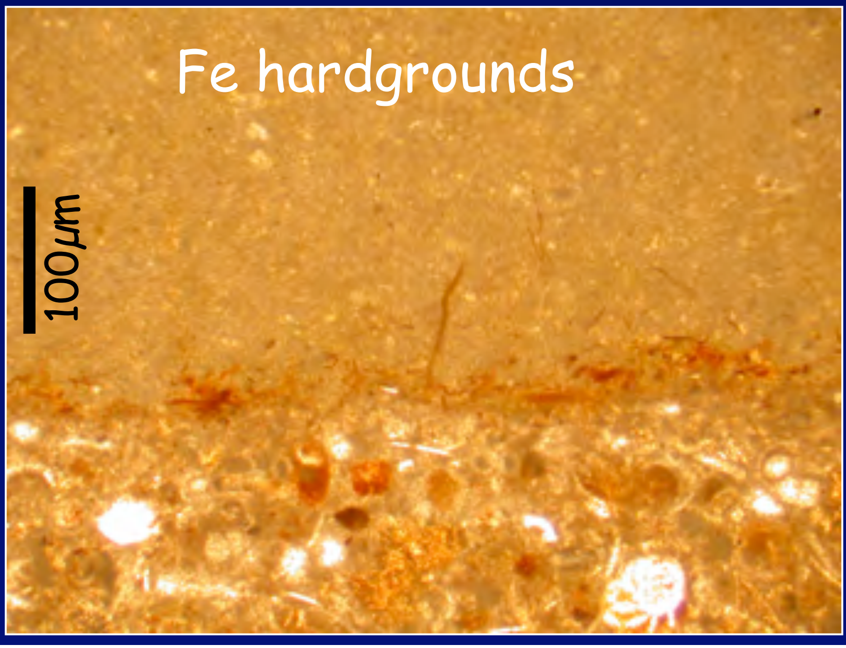


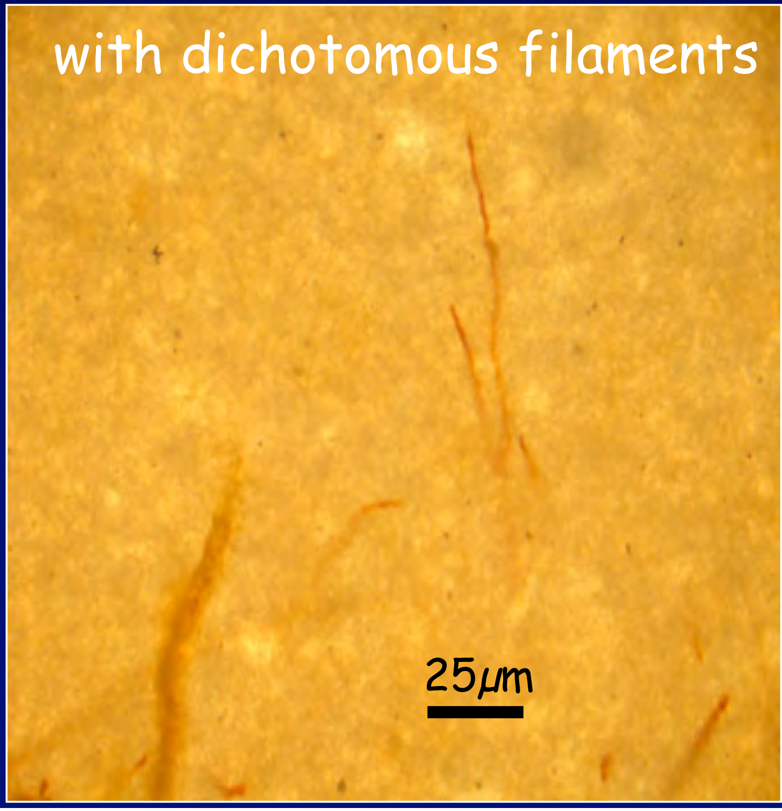


ROSSO AMMONITICO, ITALY, JURASSIC

Microstromatolites-Oncolites

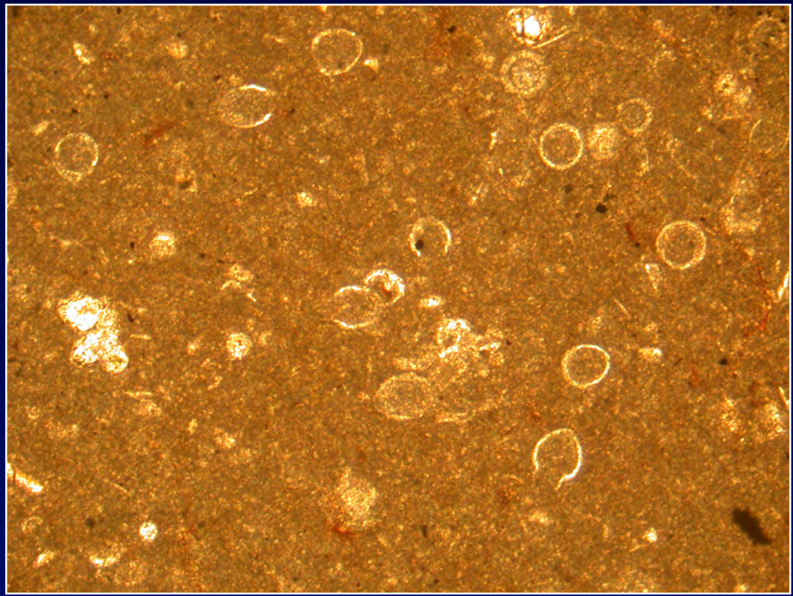




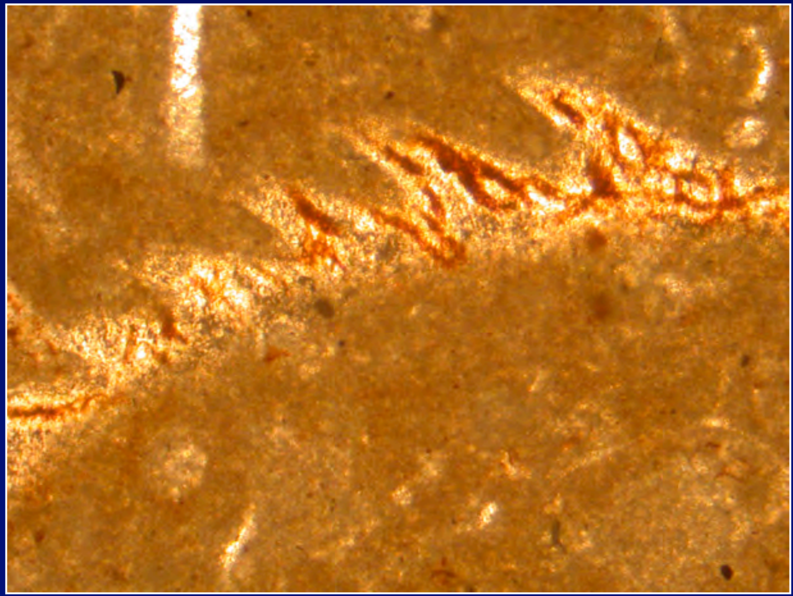


ROSSO AMMONITICO, SPAIN, JURASSIC

Calpionellids

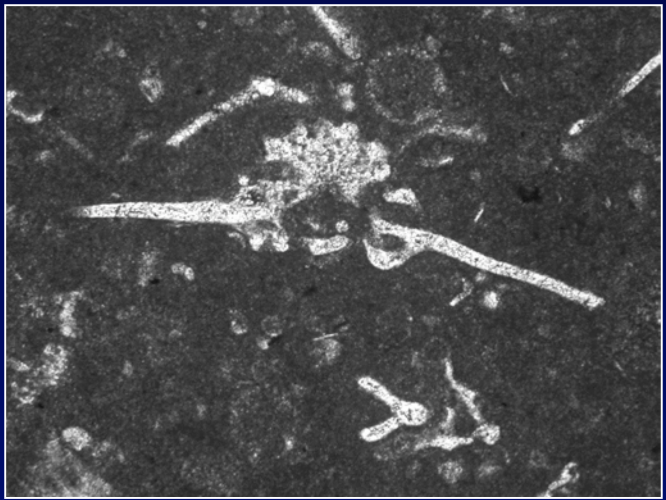
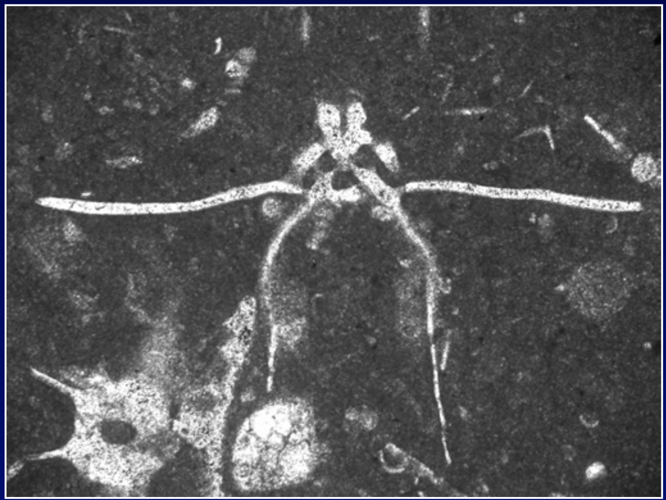


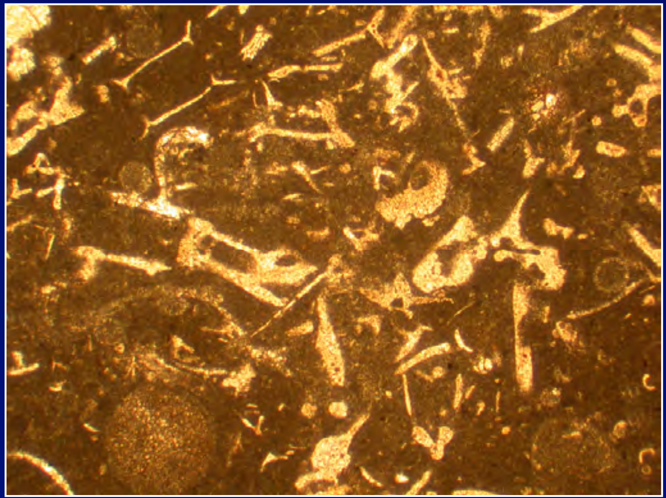
Holothuroid sclerite



ROSSO AMMONITICO, SPAIN, JURASSIC

Holothuroid-Ophiuroid packstone



first conclusion

hematite is not dispersed at random
but follows regular patterns

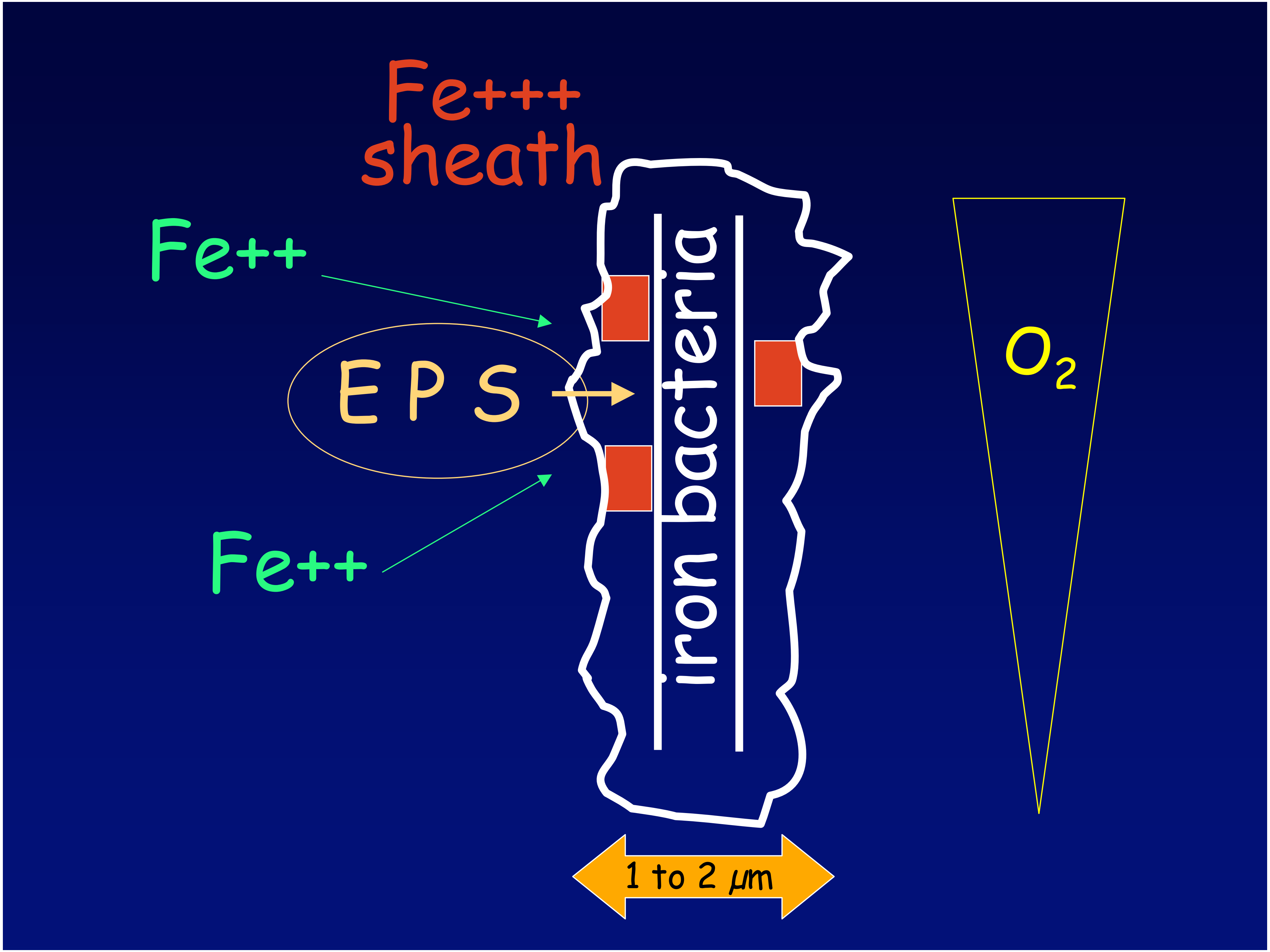
...

BIOsedimentary pathway?

1. Today they are associated with Fe and/or Mn deposits. O_2 and pH values determine the iron solubility in aqueous solutions.

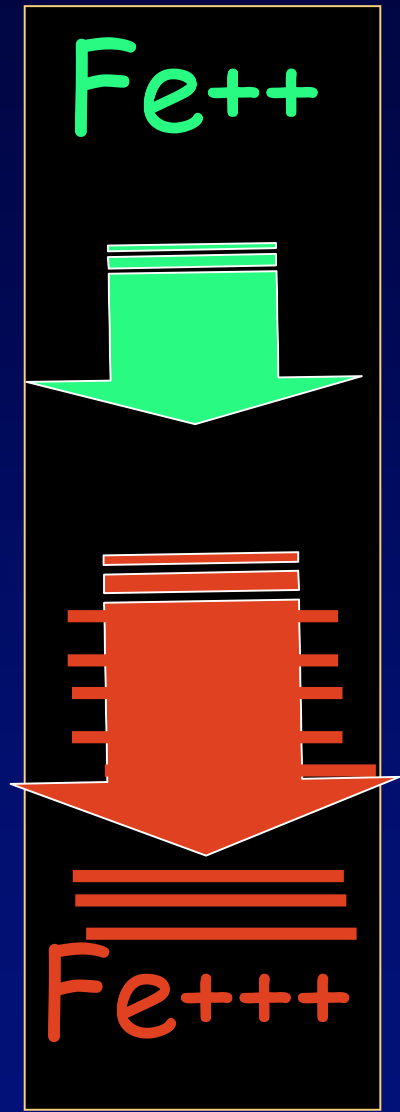
2. The neutrophile iron bacteria are associated with the oxic/anoxic interface
-*Sphaerotilus, Leptothrix, Gallionella, Beggiatoa* …

3. Iron biomineralization is linked to the production of EPS - exopolymeric substances = sheaths or capsules rich in polysaccharides forming the main part of the bacterial mats. The Fe+++ is passively precipitated in the EPS of the Recent bacterial films



Fe+++
sheath
Fe++
EPS
Fe++
iron bacteria
O2
1 to 2 µm

in the past,
coccoid and bacillar bacteria associated with other micro-fossils formed mineralized biofilms



MEB observations

X1000, x35000…

- simple and regular filaments
- simple filaments with regular constrictions
- dichotomic filaments with constrictions
- concentrations of regular sphaerules

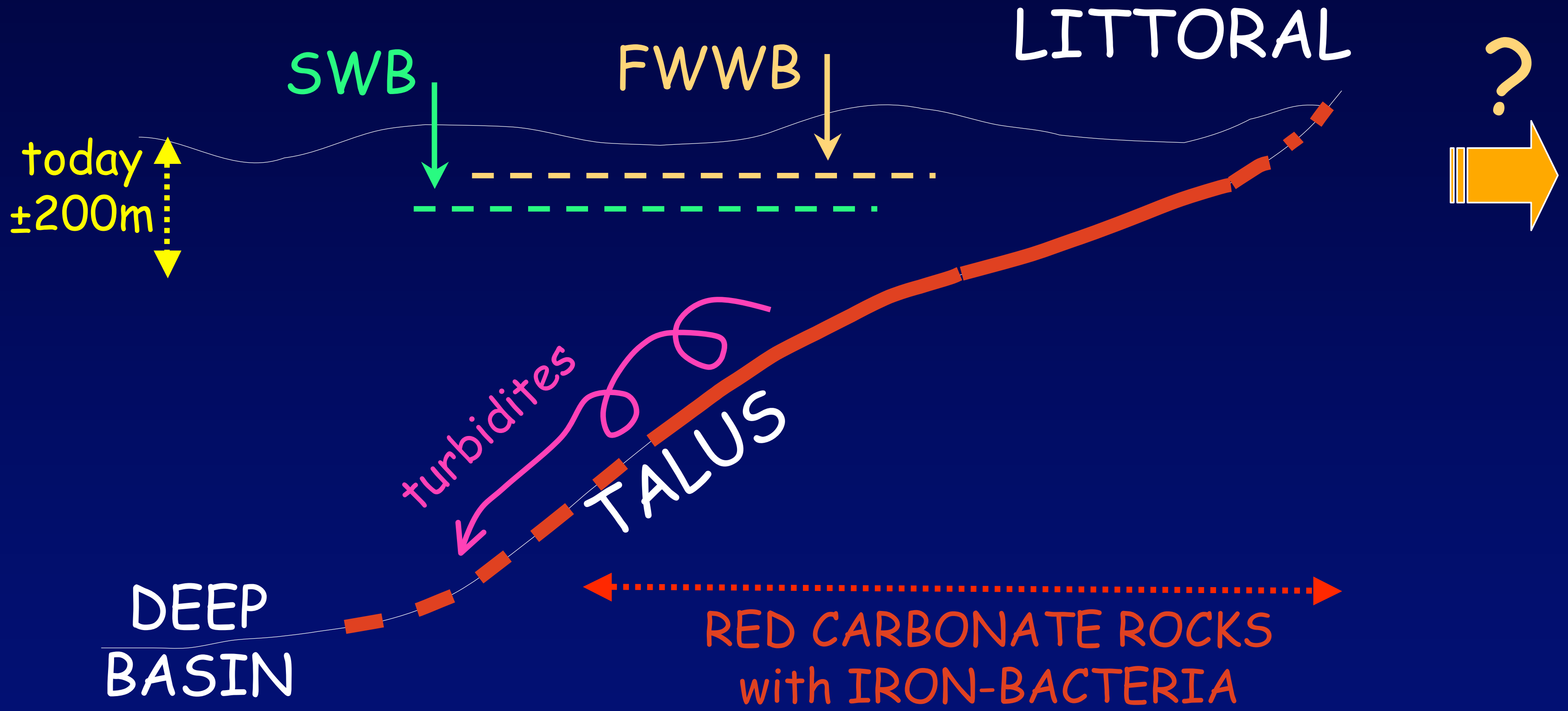
diameter: <= 2 µm
with submicronic hematite in the sheath

These morphologies are suggestive of iron bacteria

Irregular filamentous forms (10'μm), sometimes forming a network and associated with spores

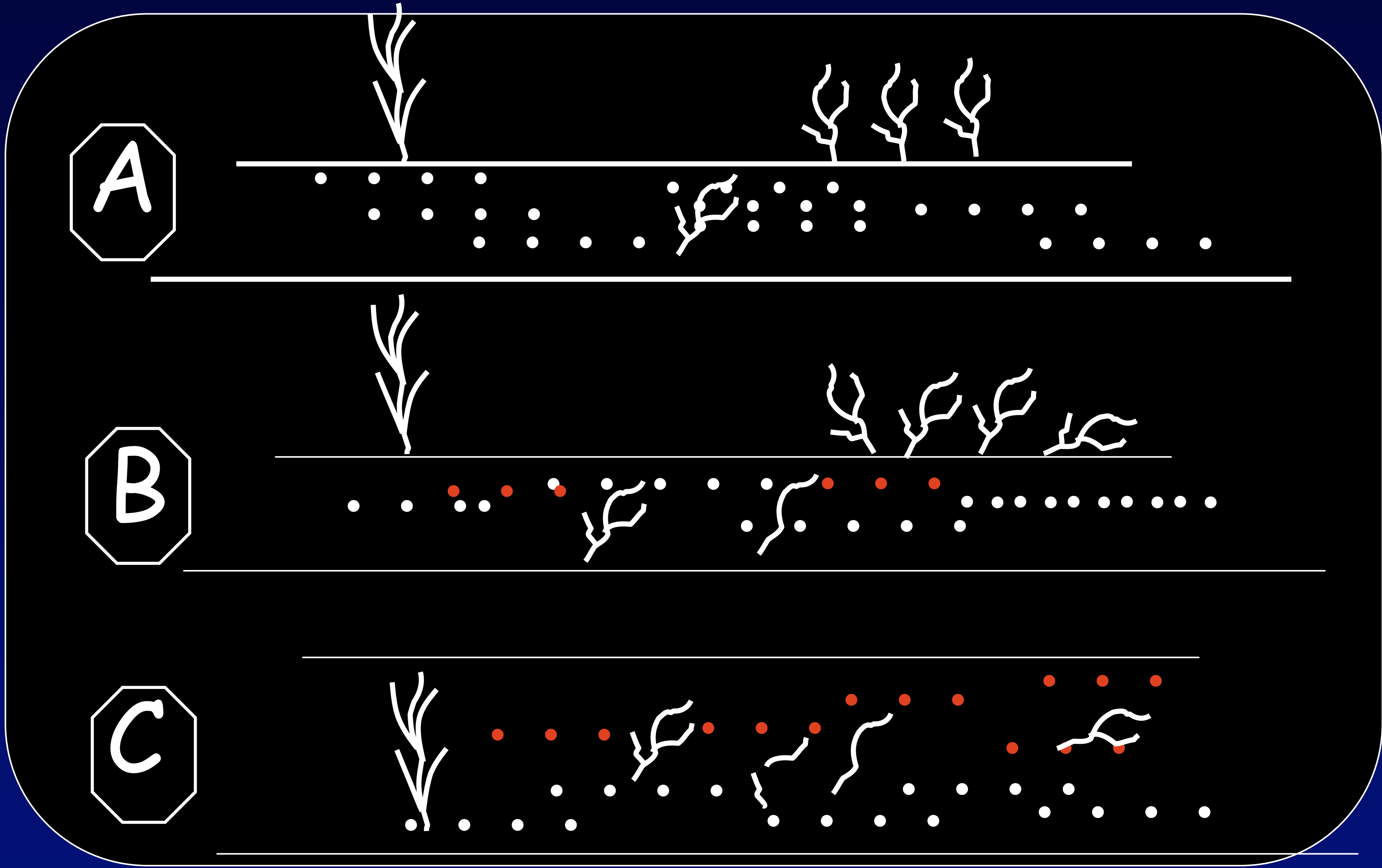
These morphs suggest the presence of FUNGI IMPERFECTI

SECOND CONCLUSION



... if iron bacteria are present, iron hydroxides are linked to an oxic/anoxic gradients in poorly oxygenated waters and independent of light

ORIGIN OF PIGMENTATION

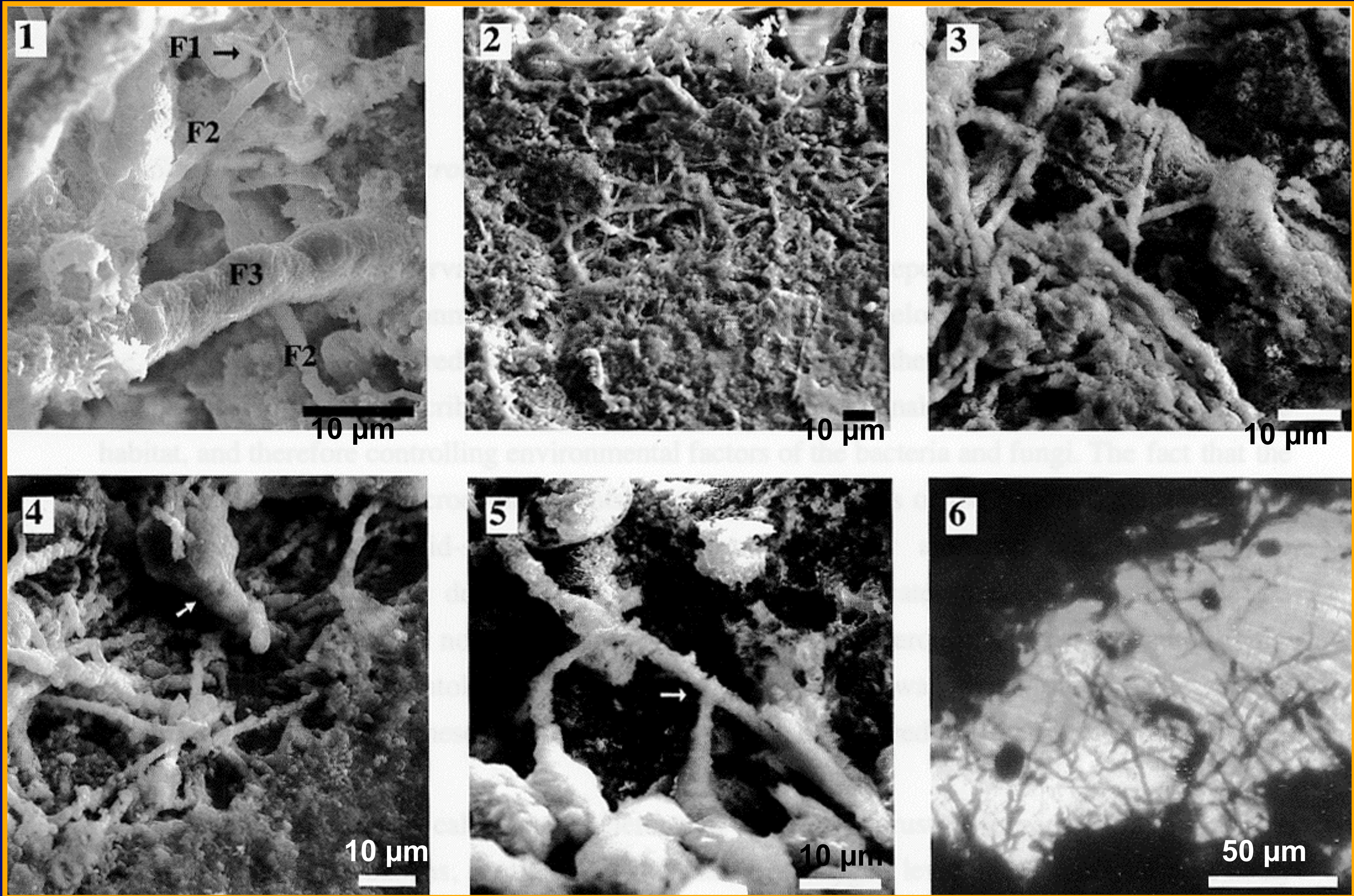


Further diagenesis will transform the micrite into a porous microspar.
Iron hydroxides are now hematite.

WHAT TO REMEMBER?

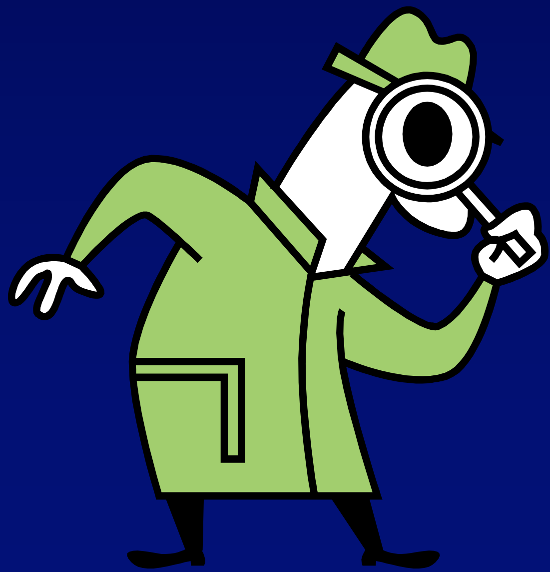
not a curiosity

BACTERIAL FILAMENTS ARE WIDESPREAD



Bajocian, SHP, France, Préat et al. 2000

FUTURE RESEARCH …




The Red Planet?