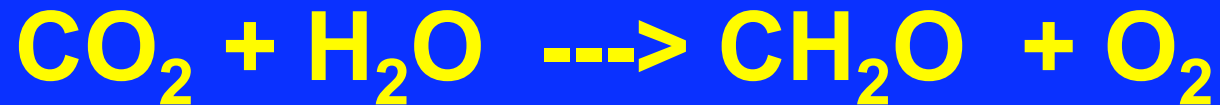
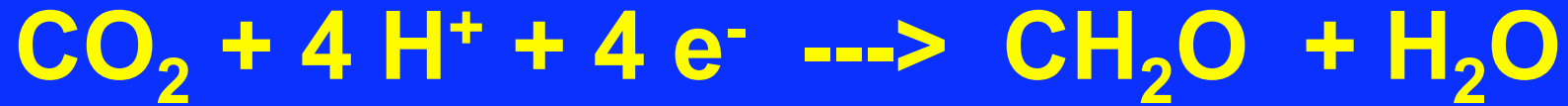


The Earth system:

A natural energy storage device

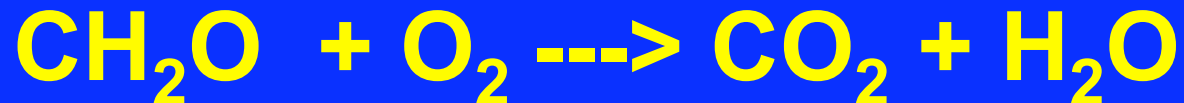
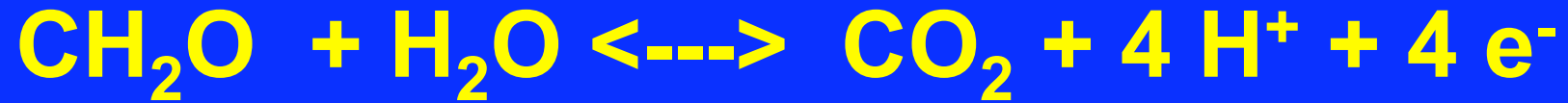
**1. System Earth is storing solar energy
on long timescales**

PHOTOSYNTHESIS



10^{16} moles of C/yr

RESPIRATION



10^{16} moles of C/yr

Carbon cycle

ATMOSPHERE
 $6 \cdot 10^{16}$ mol

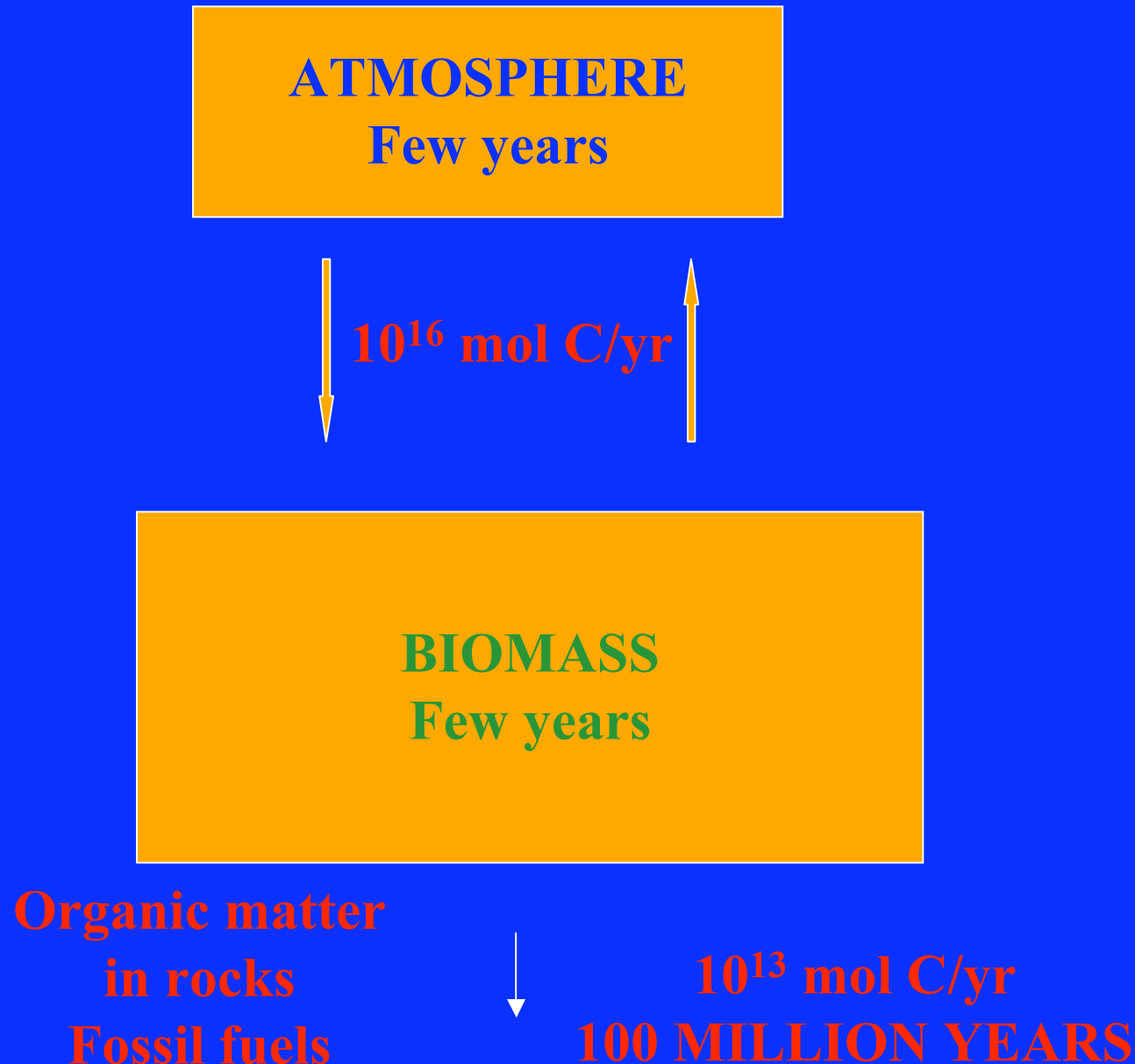
10^{16} mol C/yr

BIOMASS
 10^{17} mol

**Organic matter
in rocks
Fossil fuels**

10^{13} mol C/yr

Notion of residence time



A very long term equilibrium

$$\delta C_{\text{org}} = -25 \text{ pmil}$$

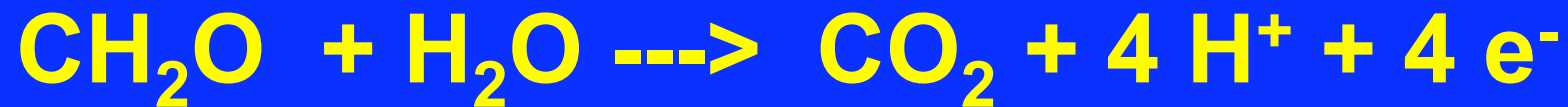
$$\delta C_{\text{ox}} = 0$$

$$\delta C_{\text{tot}} = -5 \text{ pmil}$$

$$\delta C_{\text{tot}} = X\delta C_{\text{org}} + (1-X)\delta C_{\text{ox}}$$

$$X = 0.2$$

Efficiency of energy accumulation is linked to deep biosphere metabolisms

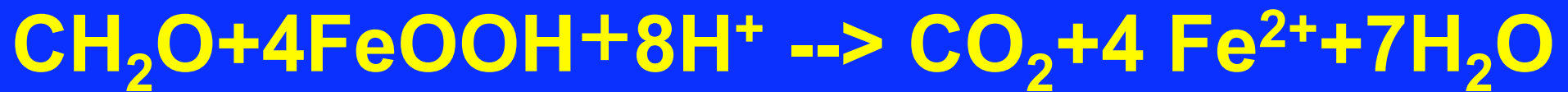
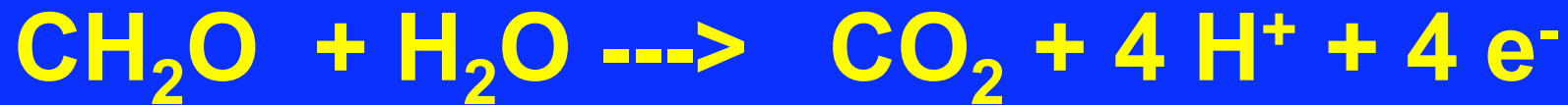


Electron Acceptors in subsurface

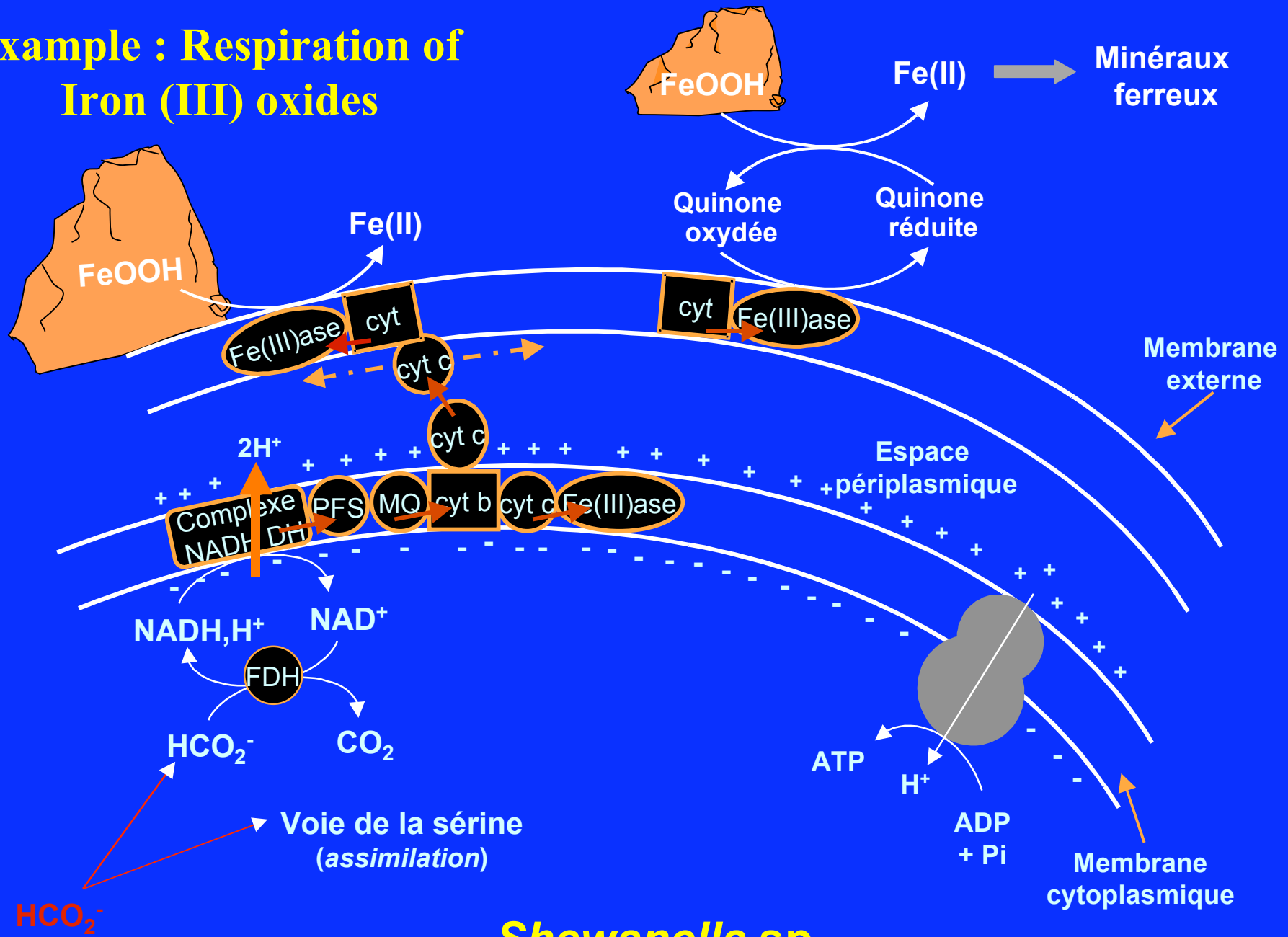
$-\text{SO}_4^{2-}$ (sulfate reducers)

$-\text{Fe}^{3+}$ (ferric iron reducers)

Example :
dissimilatory iron reducing bacteria (DIRB)

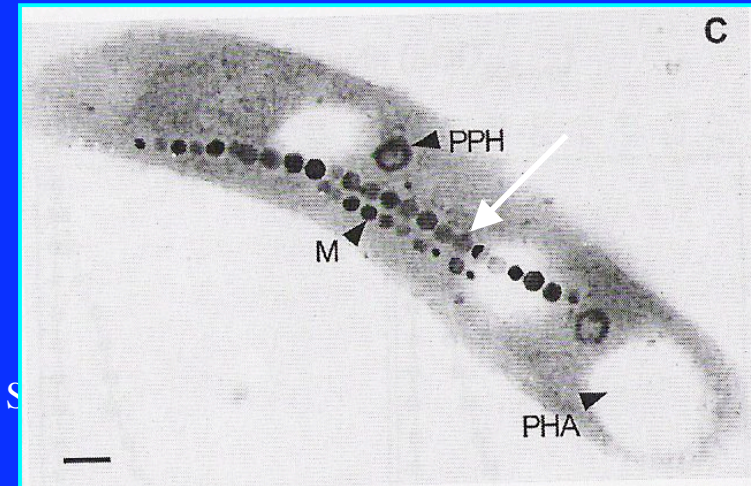


Example : Respiration of Iron (III) oxides

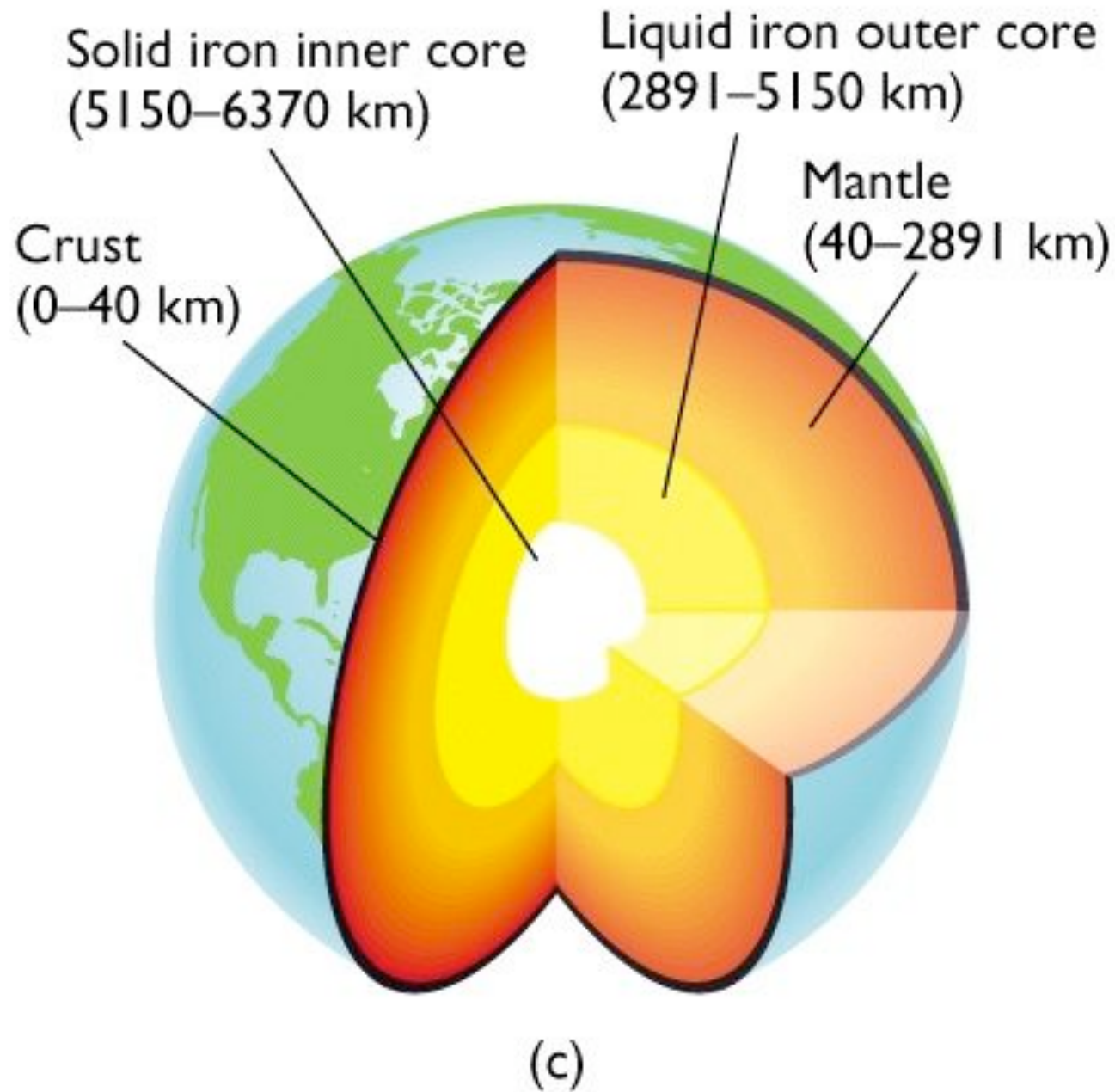


Shewanella sp.

AN INTERESTING BY-PRODUCT (MATERIAL SCIENCES) : MAGNETOTACTIC BACTERIA



**2. System Earth is retrieving energy
by oxidation of the inside by the outside**



Core = Fe(0)
Metallic alloy
(Fe,Ni,Si)

Mantle = Fe(II)
(Mg,Fe)₂SiO₄
Olivine

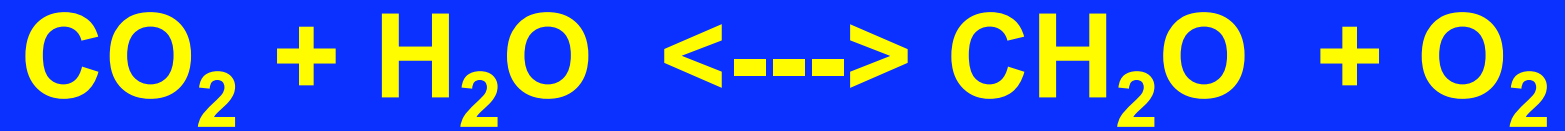
(Mg,Fe)SiO₃
Perovskite
structure

The interior of the Earth is chemically reduced (Fe/FeO)

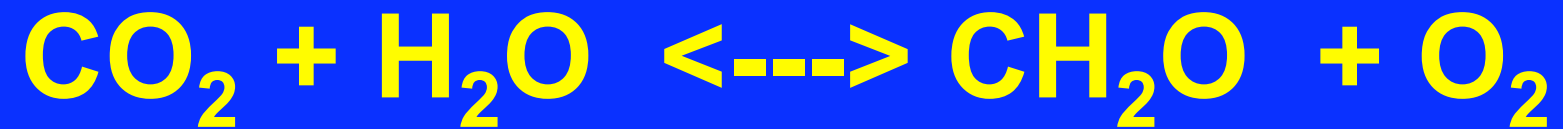
**The exterior of the Earth is chemically
oxidized (O_2/H_2O)**

**This has not always been the case
First rise of atmospheric O_2
at -2.3 Ga
(age of the Earth -4.5 Ga)**

OXYGEN PRODUCTION



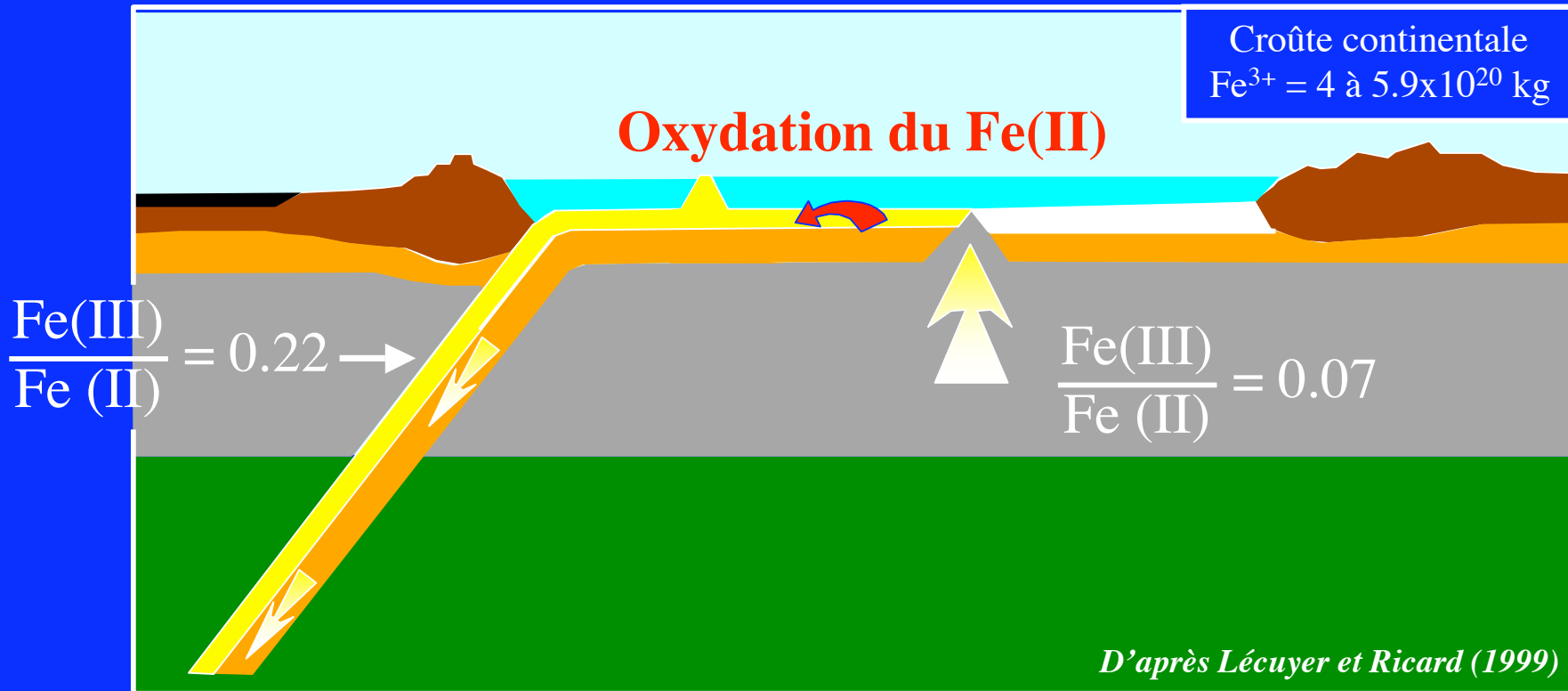
OXYGEN PRODUCTION



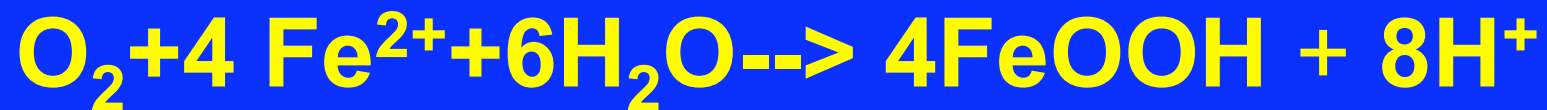
Storage of CO_2 : 10^{13} moles of C/yr

Production of O_2 : 10^{13} moles de O_2 /yr

Regulation of O₂ by plate tectonics



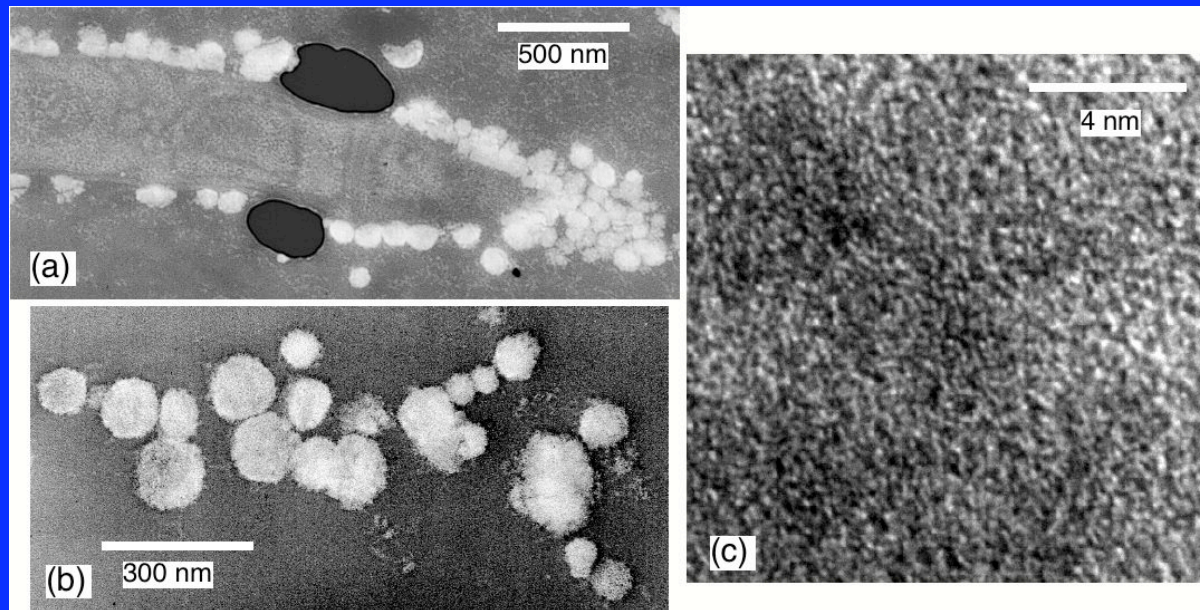
Iron oxidation at mid-oceanic ridges



**This energy resource
is used by deep ecosystems
to make biomass**

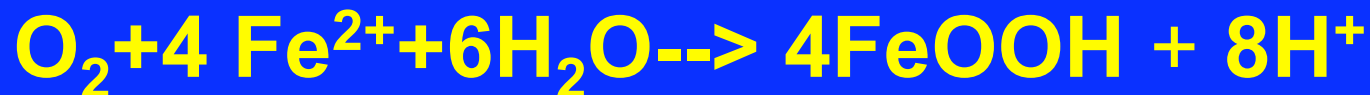


PRIMARY PRODUCTION BY IRON OXIDIZING BACTERIA

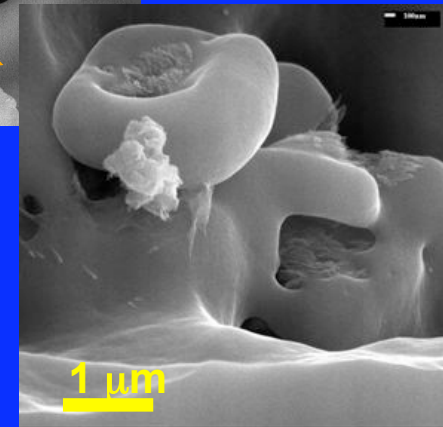
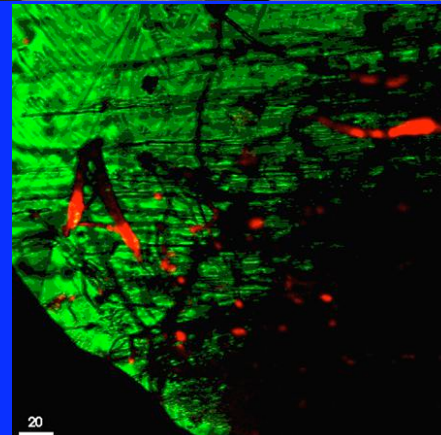
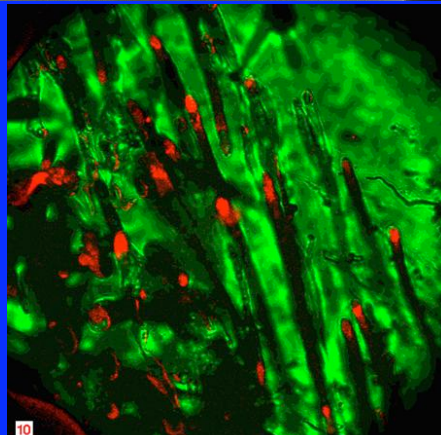
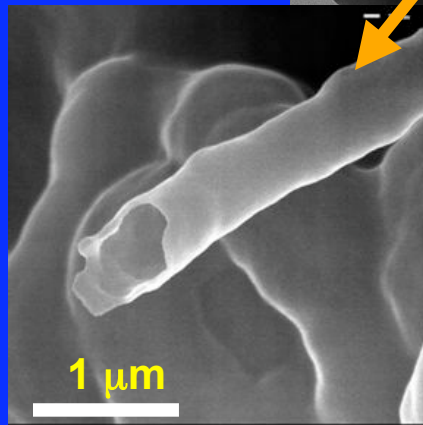
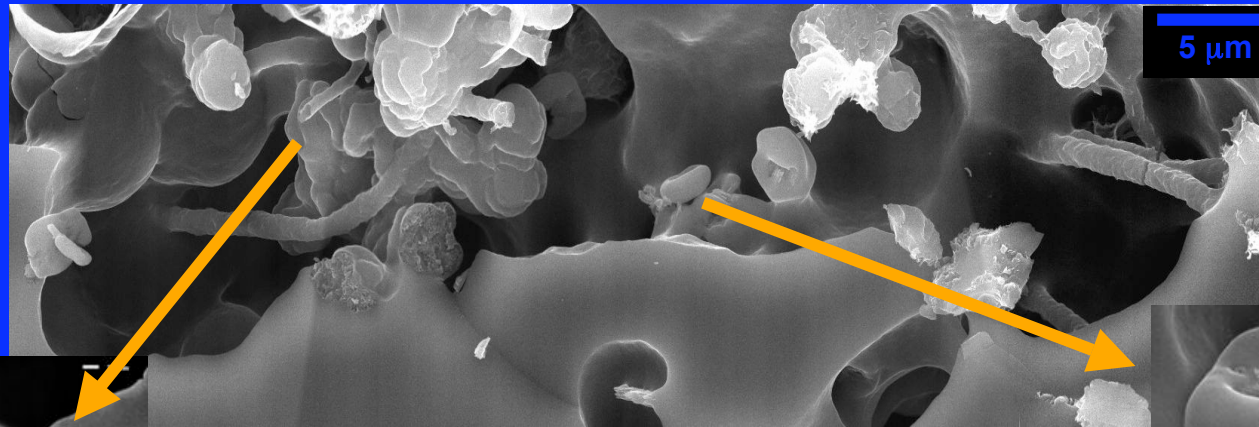


Alexandre Gloter, Magali Zbinden et al.
Image : Alexandre Gloter LPS
Projet Geomex : Hydrothermalisme

Iron-oxidizing bacteria



Biological alteration of solids



Ethidium Bromide staining in channels (DNA?)

Channels have been interpreted as biogenic weathering features



Important implications for global geochemistry and search for ancient traces of life

Reducing power of the inside Earth: Hydrogen generation



Role of high temperatures

Reducing power of the inside Earth: Hydrogen generation



Natural H₂ as an energy source?