



IS HELICOIDAL GREEN RUST THE MISSING LINK BETWEEN HYDROTHERMAL CHEMISTRY AND BIOCHEMISTRY?

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ON
GROWTH AND FORM

BY
D'ARCY WENTWORTH THOMPSON

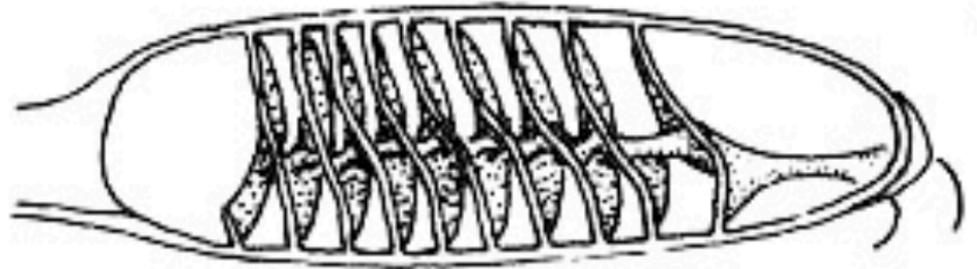


Cambridge :
at the University Press
1917

A deal of evolution is involved in keeping due balance
between surface and mass as growth goes on ...

of these ...
the helicoid spiral is the most interesting to the biologist

... e.g.,
the "spiral valve" of the shark's gut





young sun

Hadean atmosphere

$H_2O > CO_2 > N_2 > SO_2 > CO > NO > S_8 > H_2S > H_2 > P_4O_{10} \downarrow$

$Fe^{III} & Mn^{IV}$

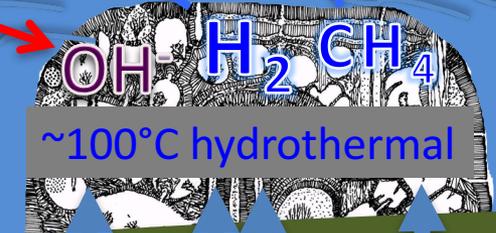
disequilibria

CARBONIC OCEAN

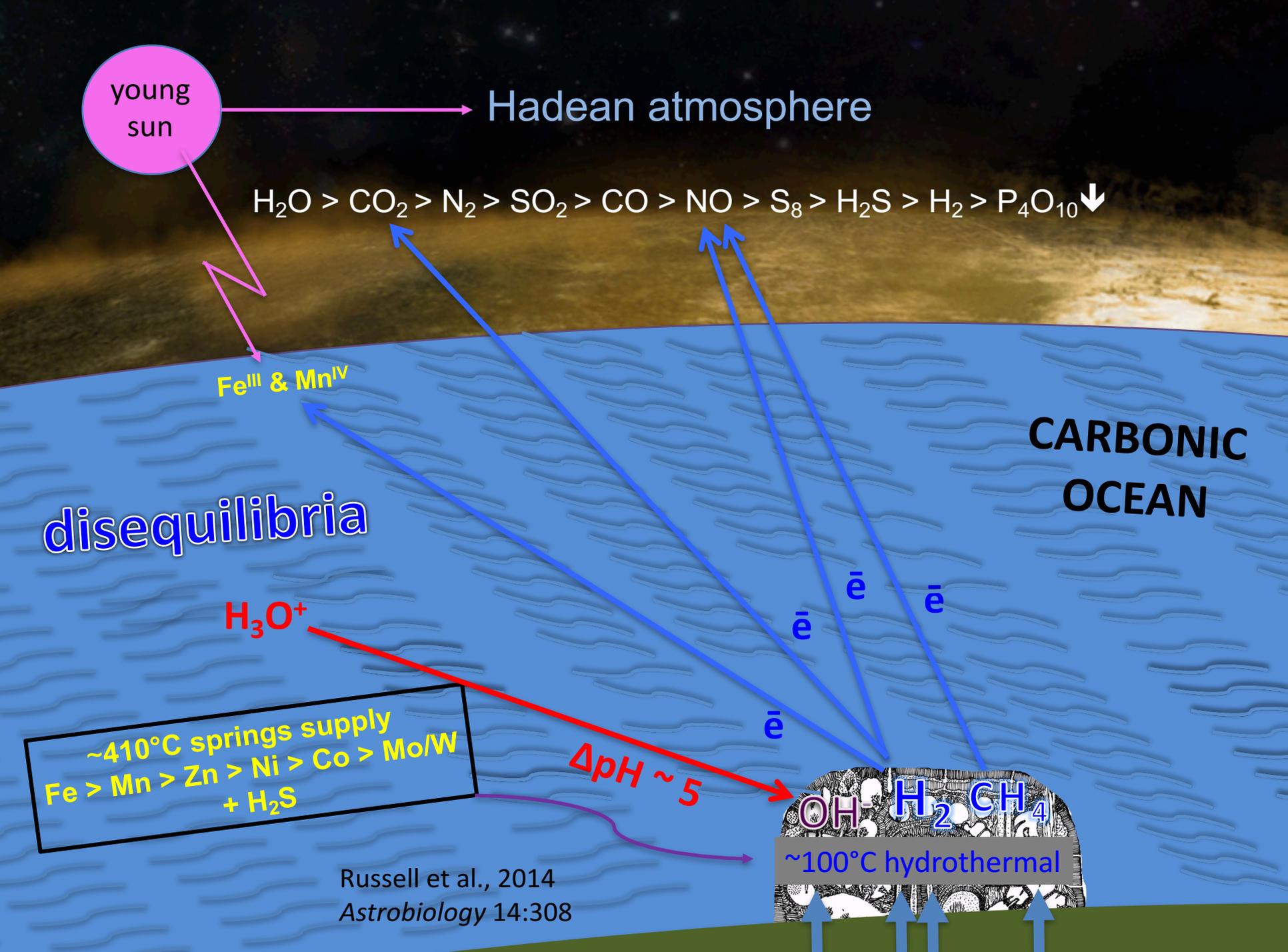
H_3O^+

~410°C springs supply
 $Fe > Mn > Zn > Ni > Co > Mo/W$
+ H_2S

$\Delta pH \sim 5$

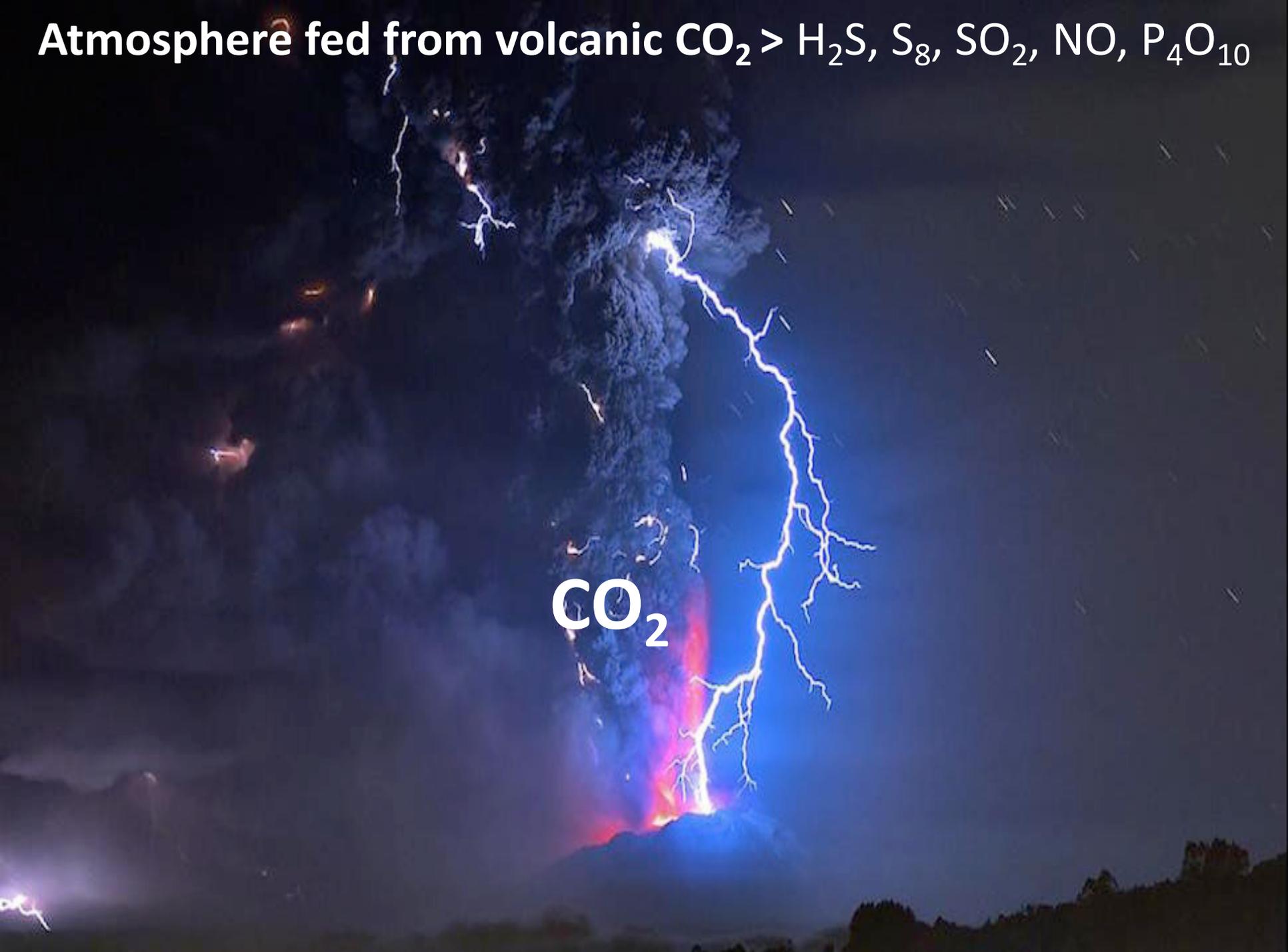


Russell et al., 2014
Astrobiology 14:308

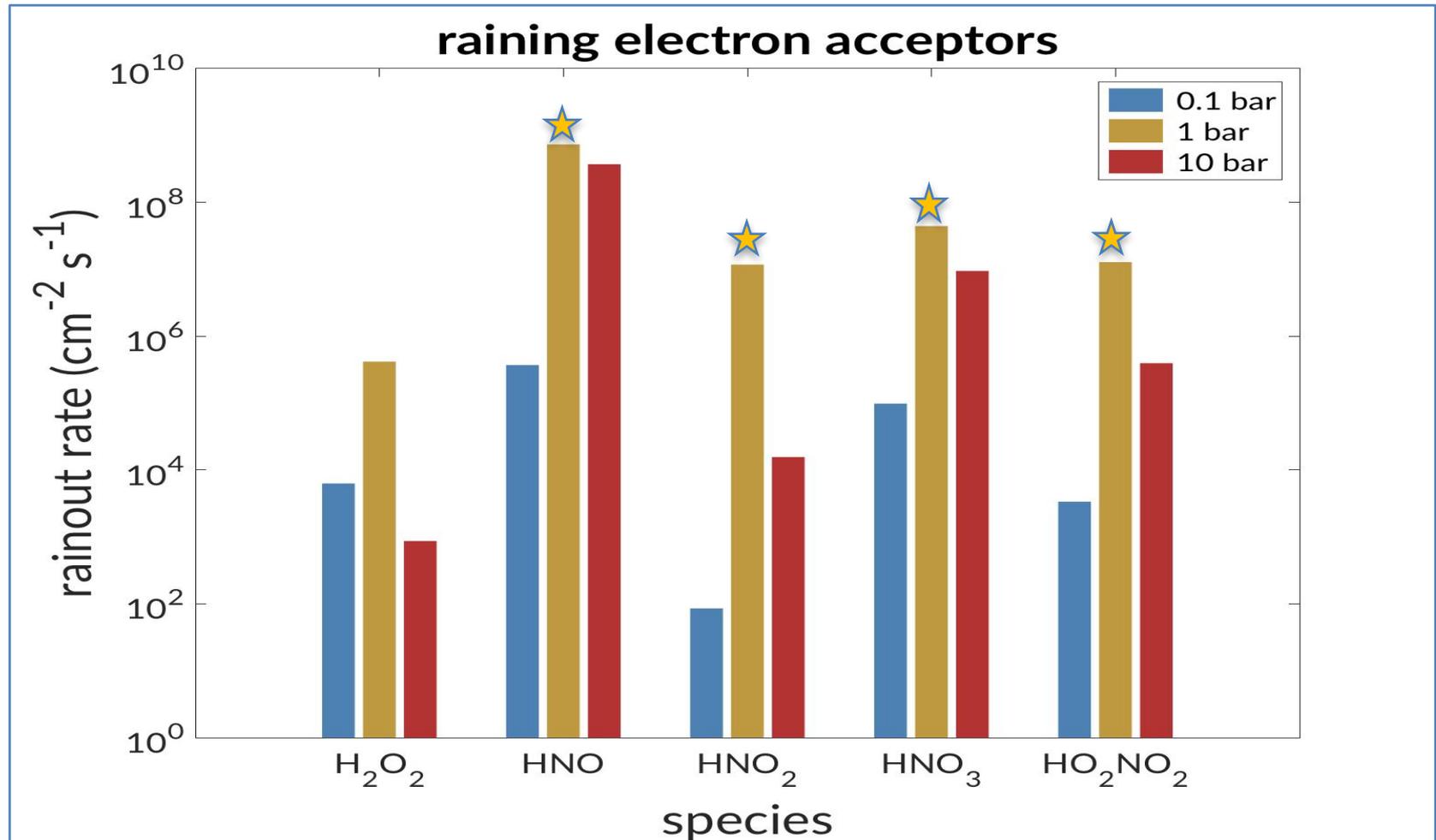


Atmosphere fed from volcanic $\text{CO}_2 > \text{H}_2\text{S}, \text{S}_8, \text{SO}_2, \text{NO}, \text{P}_4\text{O}_{10}$

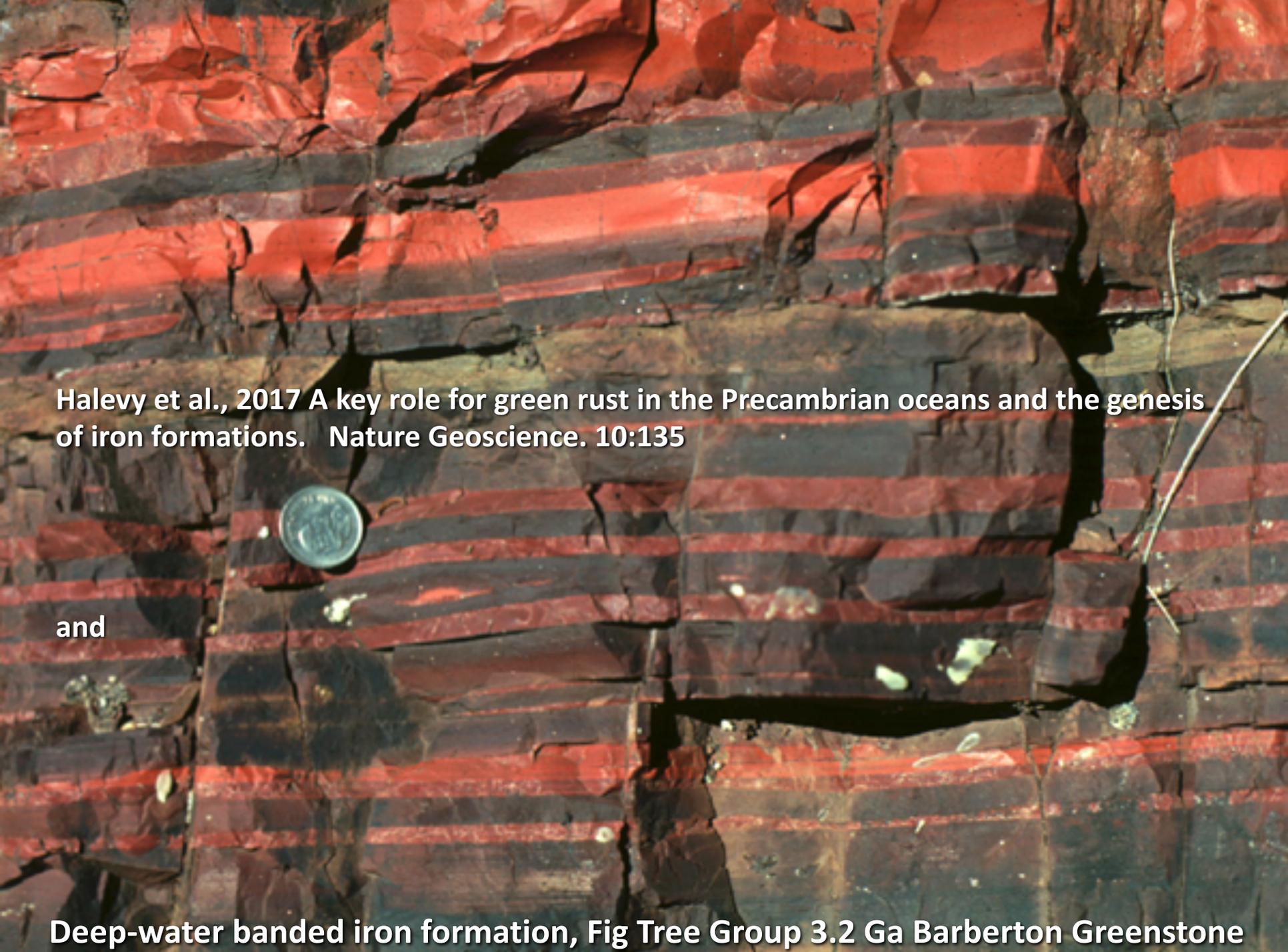
CO_2

A dramatic night-time photograph of a volcanic eruption. A massive, dark plume of ash and smoke rises from a mountain, illuminated from below by a mix of red and blue light. Several bright, jagged lightning bolts strike the plume, creating a stark contrast against the dark sky. The foreground shows the dark silhouette of a landscape with some trees. The text 'CO2' is overlaid in white on the lower part of the ash plume.

1 bar CO₂ favors



Rainout of NO_x → micromolar concentration of nitrate at steady state



Halevy et al., 2017 A key role for green rust in the Precambrian oceans and the genesis of iron formations. *Nature Geoscience*. 10:135

and

Deep-water banded iron formation, Fig Tree Group 3.2 Ga Barberton Greenstone

Fe-mound formation in a low-temperature hydrothermal system at the Jan Mayen Vent Fields

Johannessen et al. 2017 *Geochim Cosmochim Acta* 202:101-123.

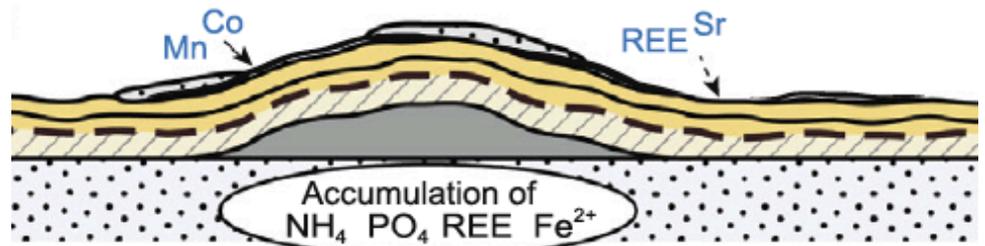
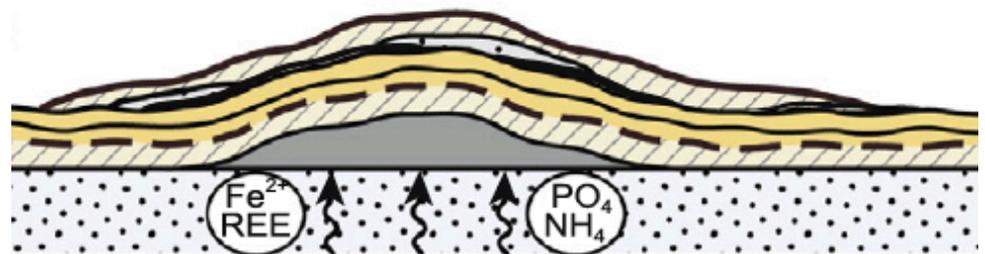
cf

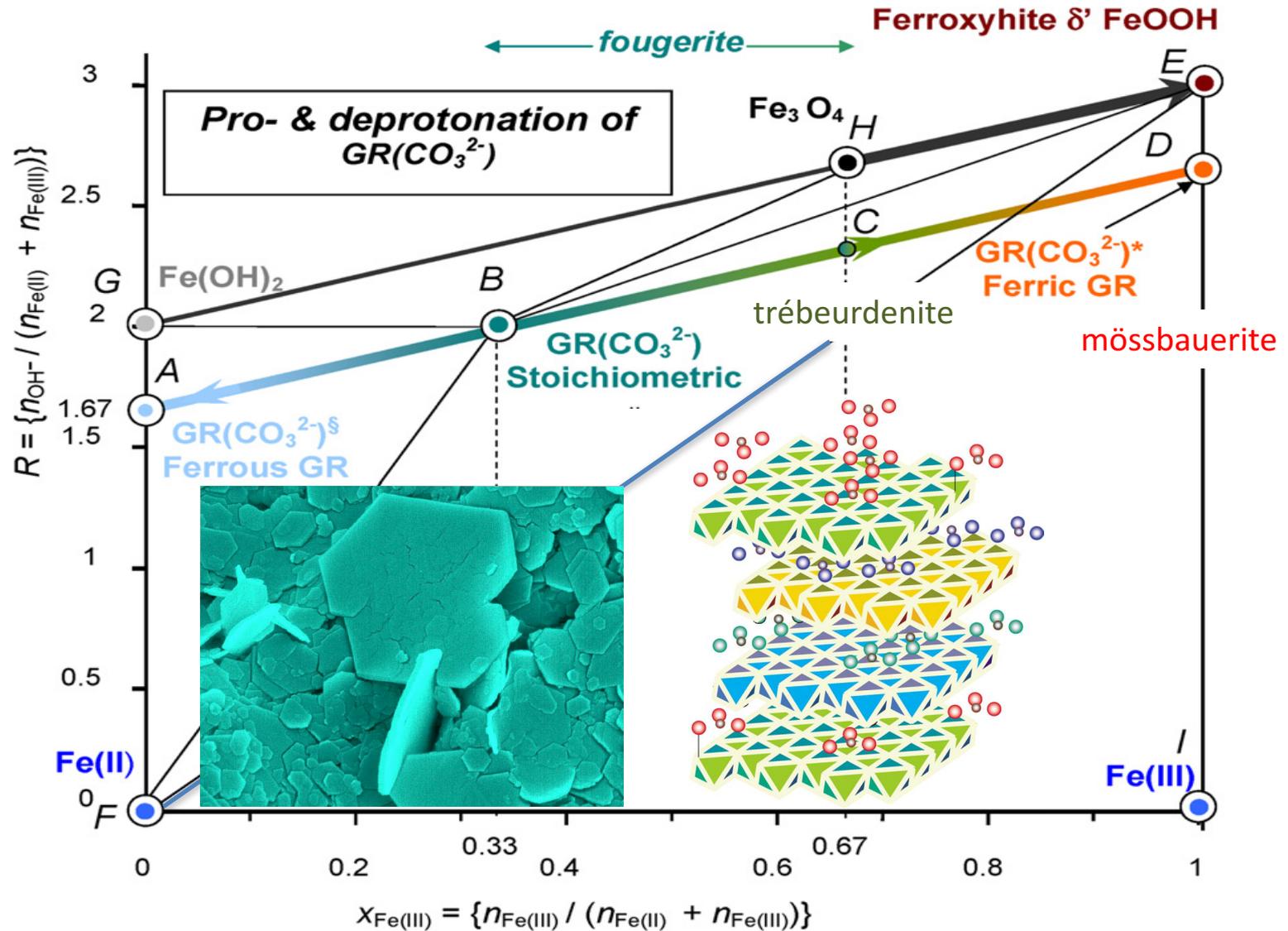
Fe-Si-oxyhydroxide deposits at The Lilliput hydrothermal field

Dekov et al. 2010 *Chem Geol* 278:186–200



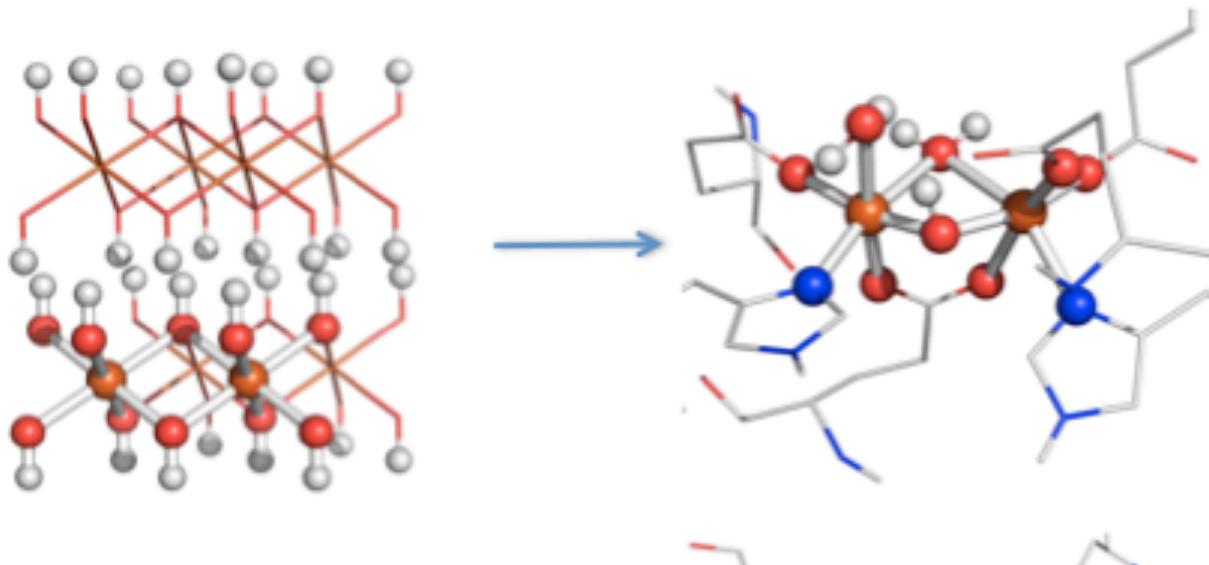
The Troll Wall field





Iron oxy-hydroxycarbonates obtained by protonation and deprotonation of $\text{GR}(\text{CO}_3^{2-})$
 (Génin et al. 2006 *Solid state sciences* 8:1330-1343)

Structure of Green Rust and Methane Monooxygenase active site



iron



nitrogen

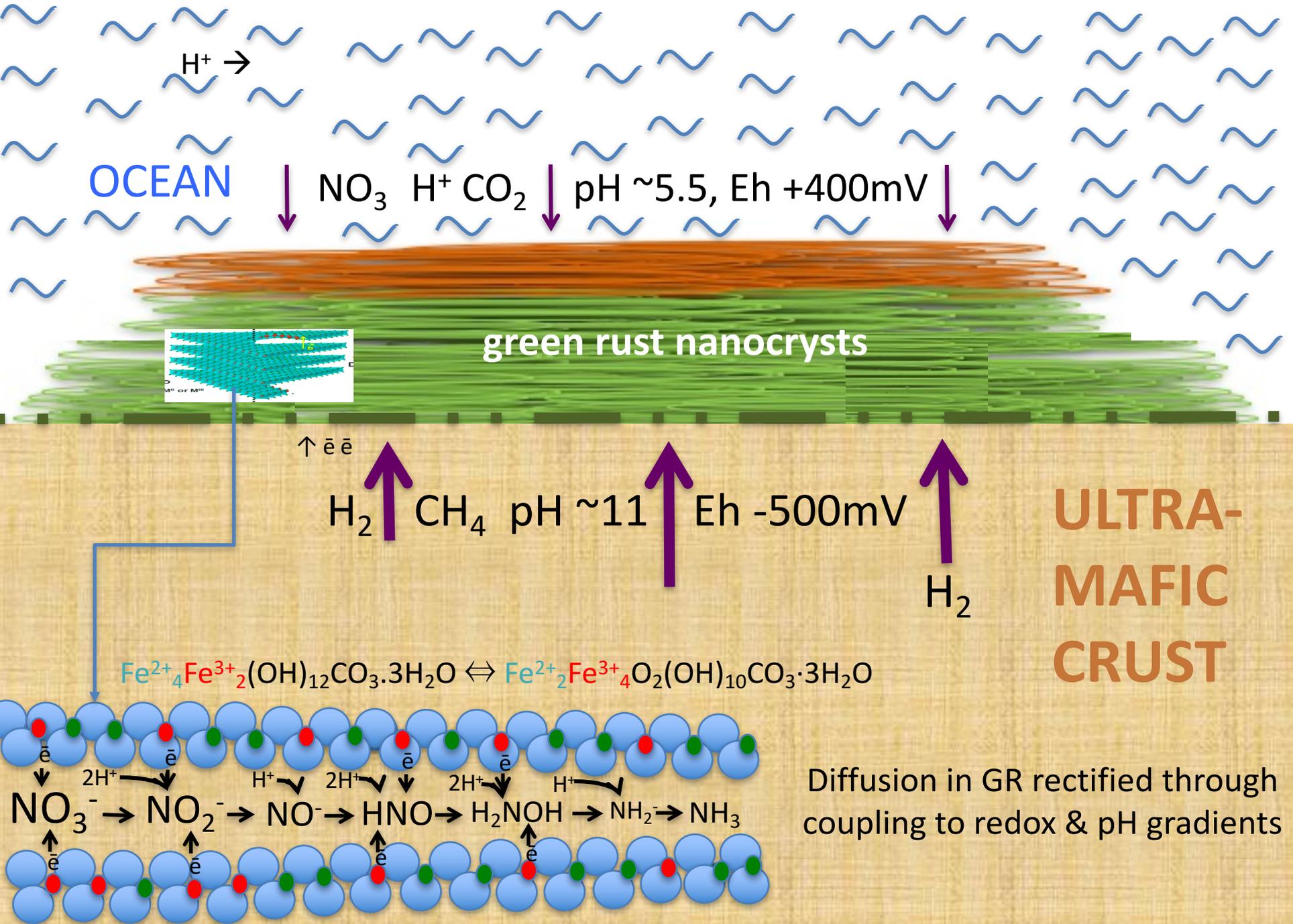


oxygen



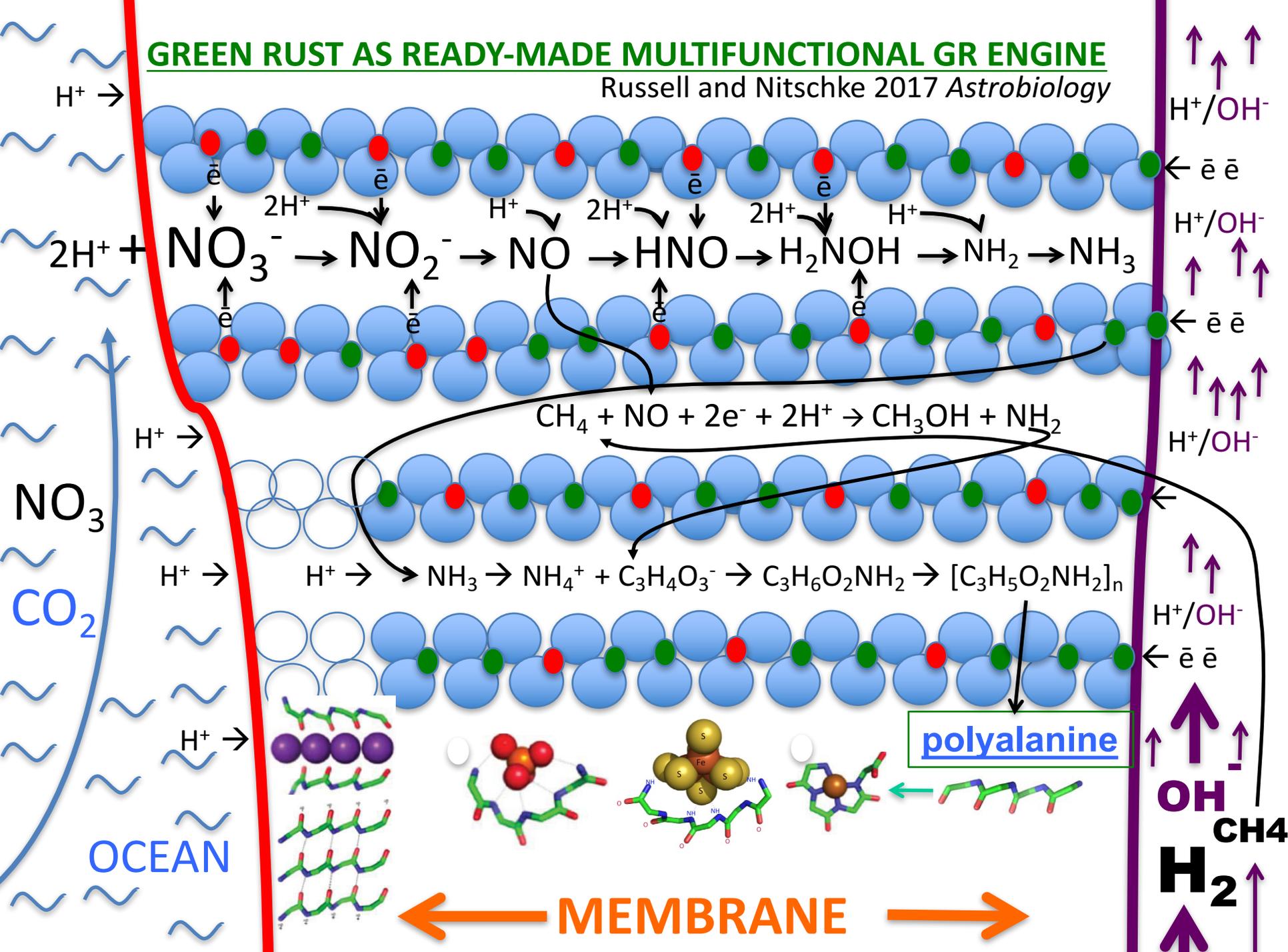
hydrogen

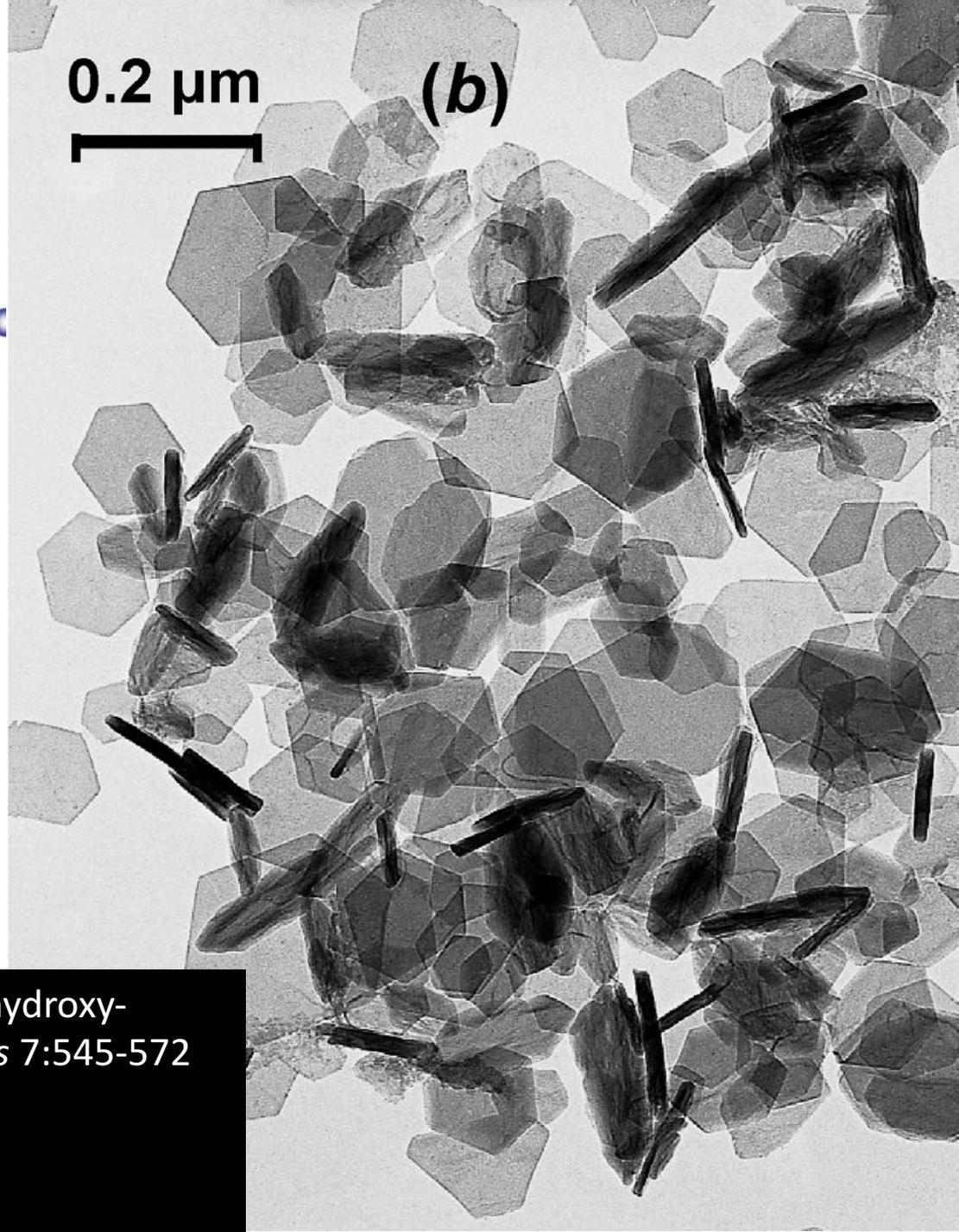
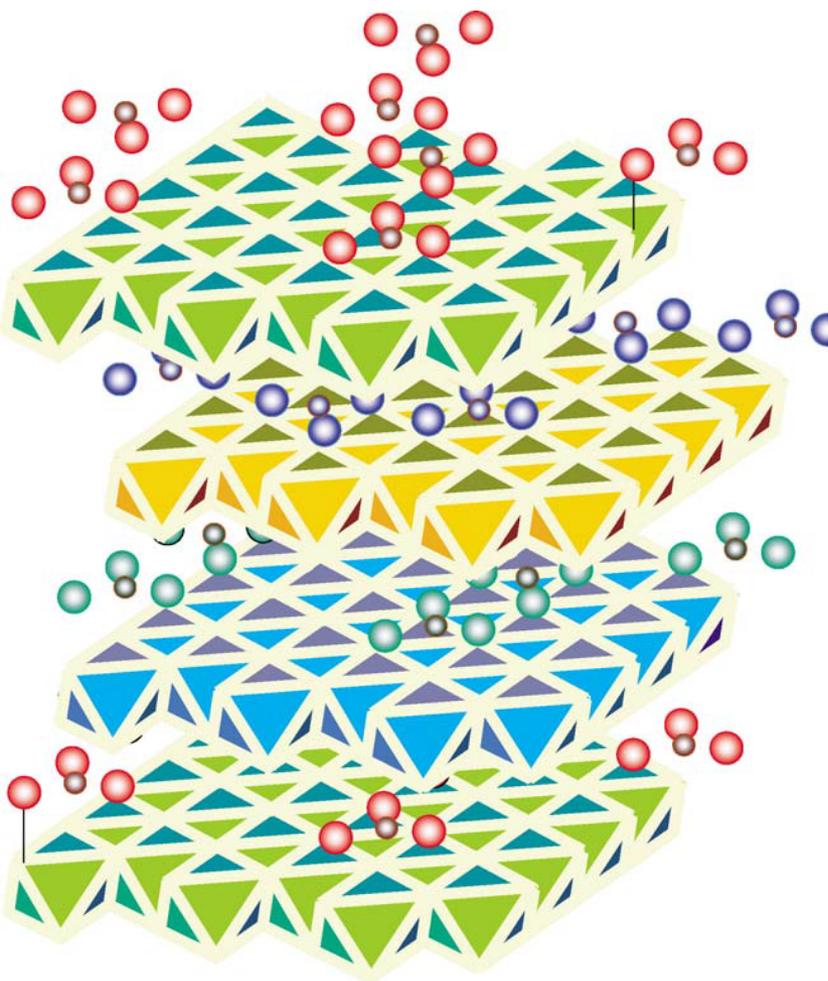
Nitschke et al., 2013 *Biochim Biophys Acta* 1827:871–881



GREEN RUST AS READY-MADE MULTIFUNCTIONAL GR ENGINE

Russell and Nitschke 2017 *Astrobiology*



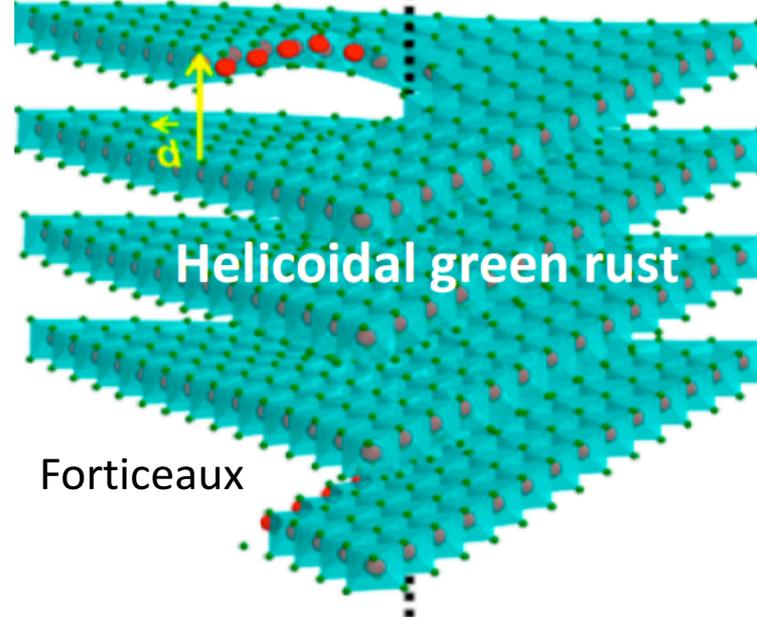
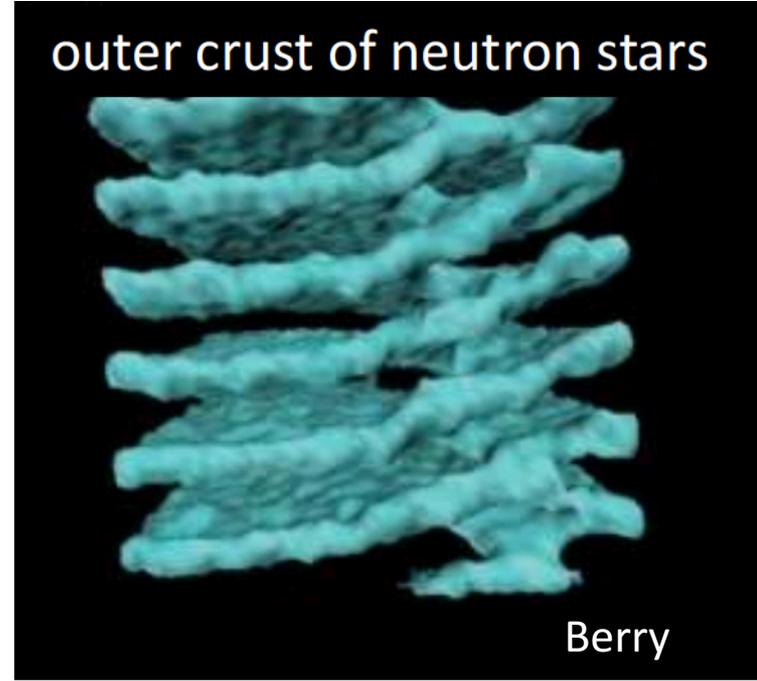
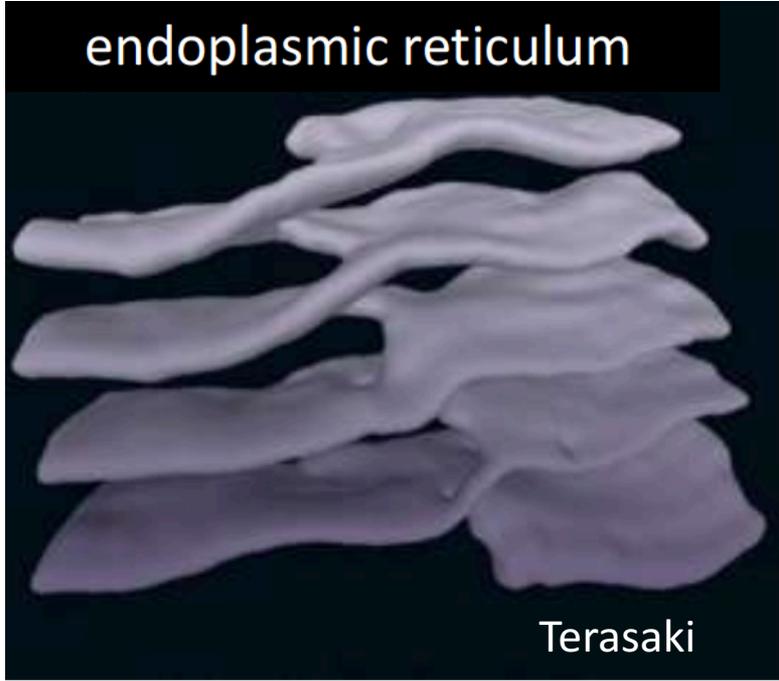


Génin et al. 2005 Fougerite and Fe II–III hydroxy-carbonate green rust. *Solid State Sciences* 7:545-572

How bodily surface can keep pace with volume – the parking garage structure

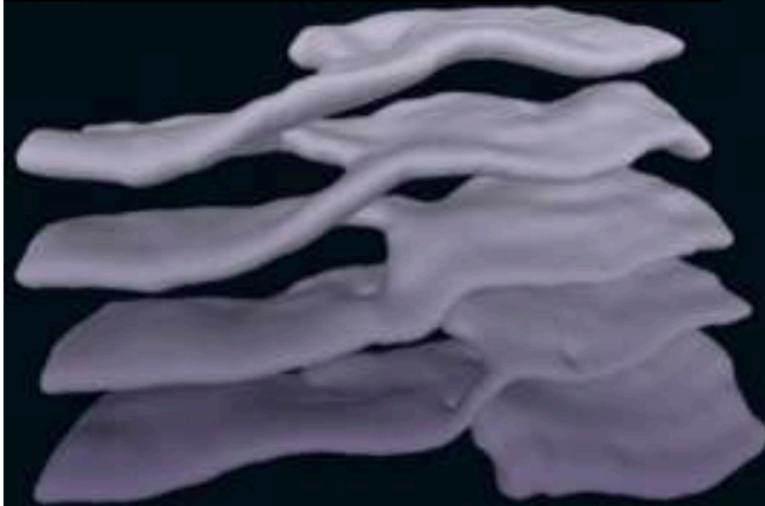


"spiral valve" of the shark's gut
D'Arcy Thompson



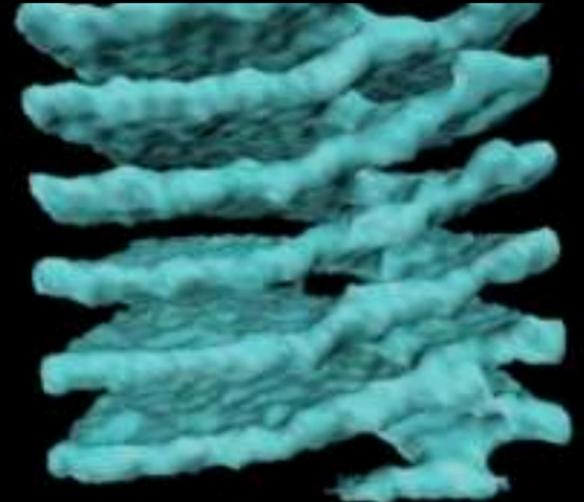
How bodily surface can keep pace with volume – the parking garage structure

endoplasmic reticulum



Terasaki et al. 2013 *Cell* 154:285-296

outer crust of neutron stars

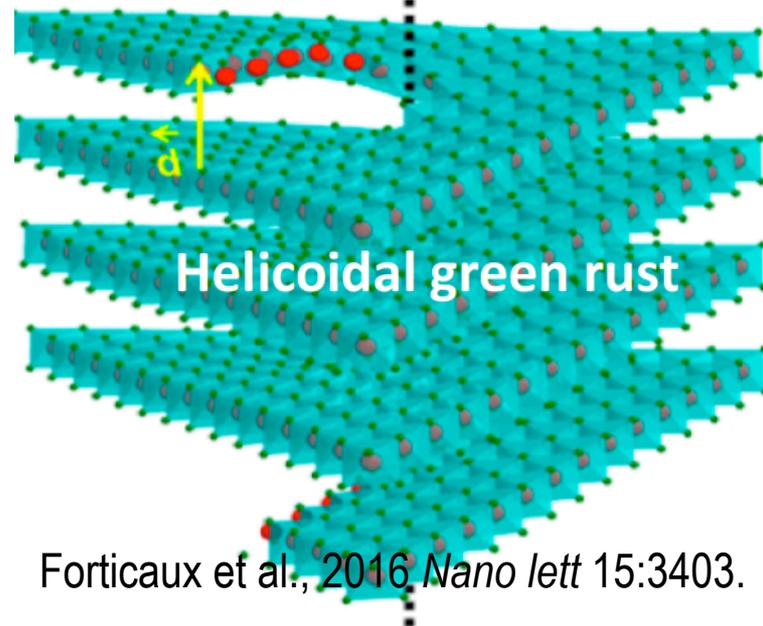


Berry et al. 2016 *Phys Rev C*, 94:55801

cf. expansion
of a sphere

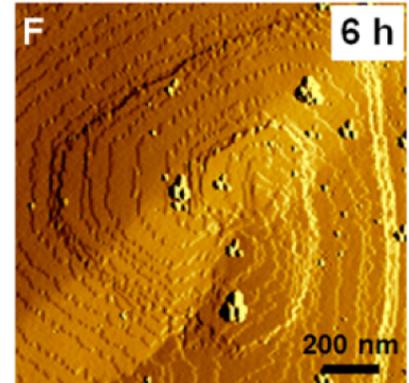
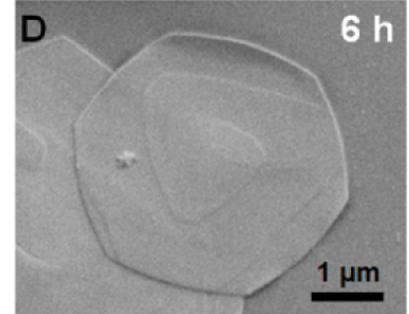
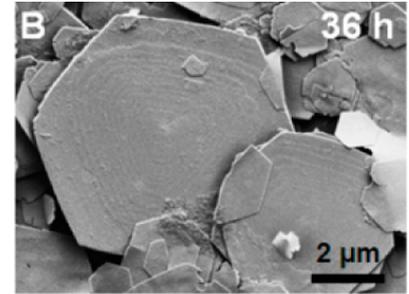
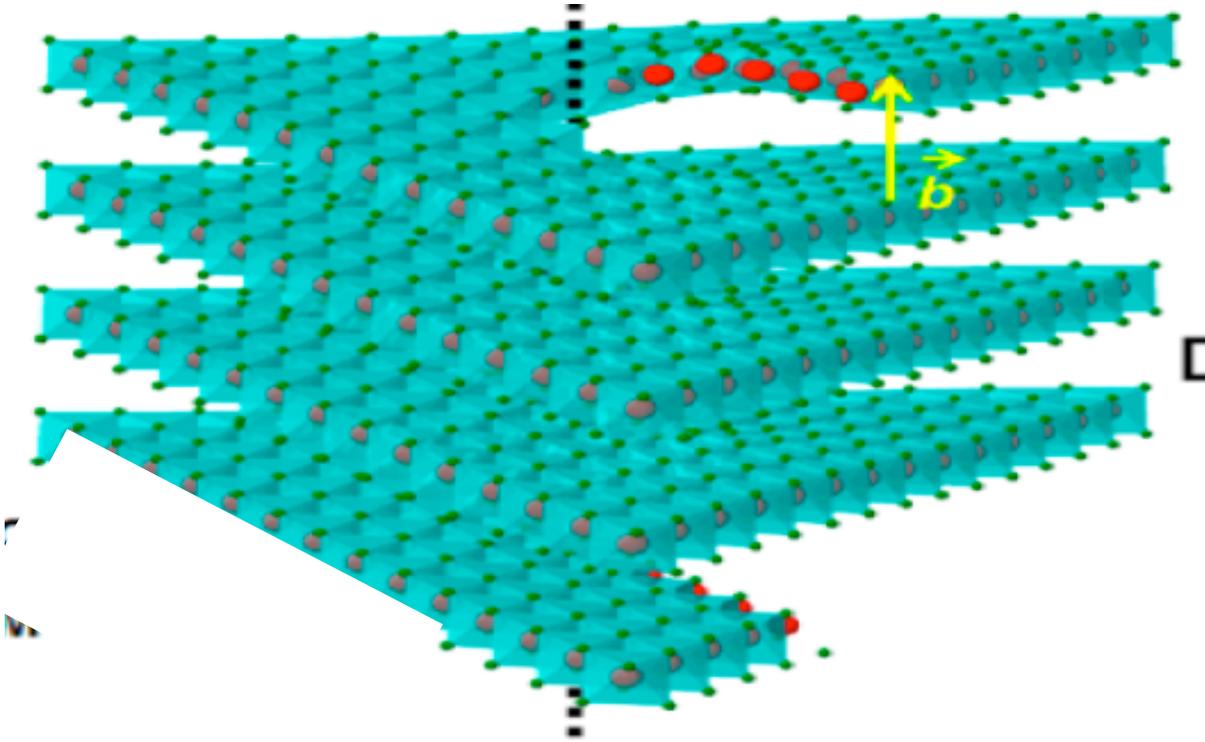
$$V = 4\pi r^3/3$$

$$S = 4\pi r^2$$



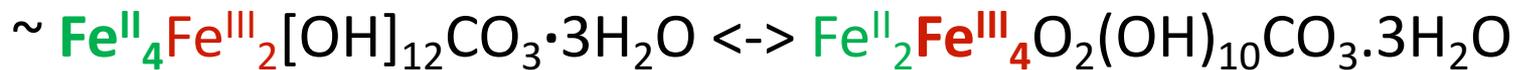
Forticaux et al., 2016 *Nano lett* 15:3403.

“Ready made” garage parking structure or helical baffle
 In this case function follows form !



Forticaux, Dang, Liang, Jin (2015) Controlled synthesis of layered double hydroxide nanoplates driven by screw dislocations. *Nano letters*, 15, 3403.

Cf. Double layer hydroxide such as “green rust”

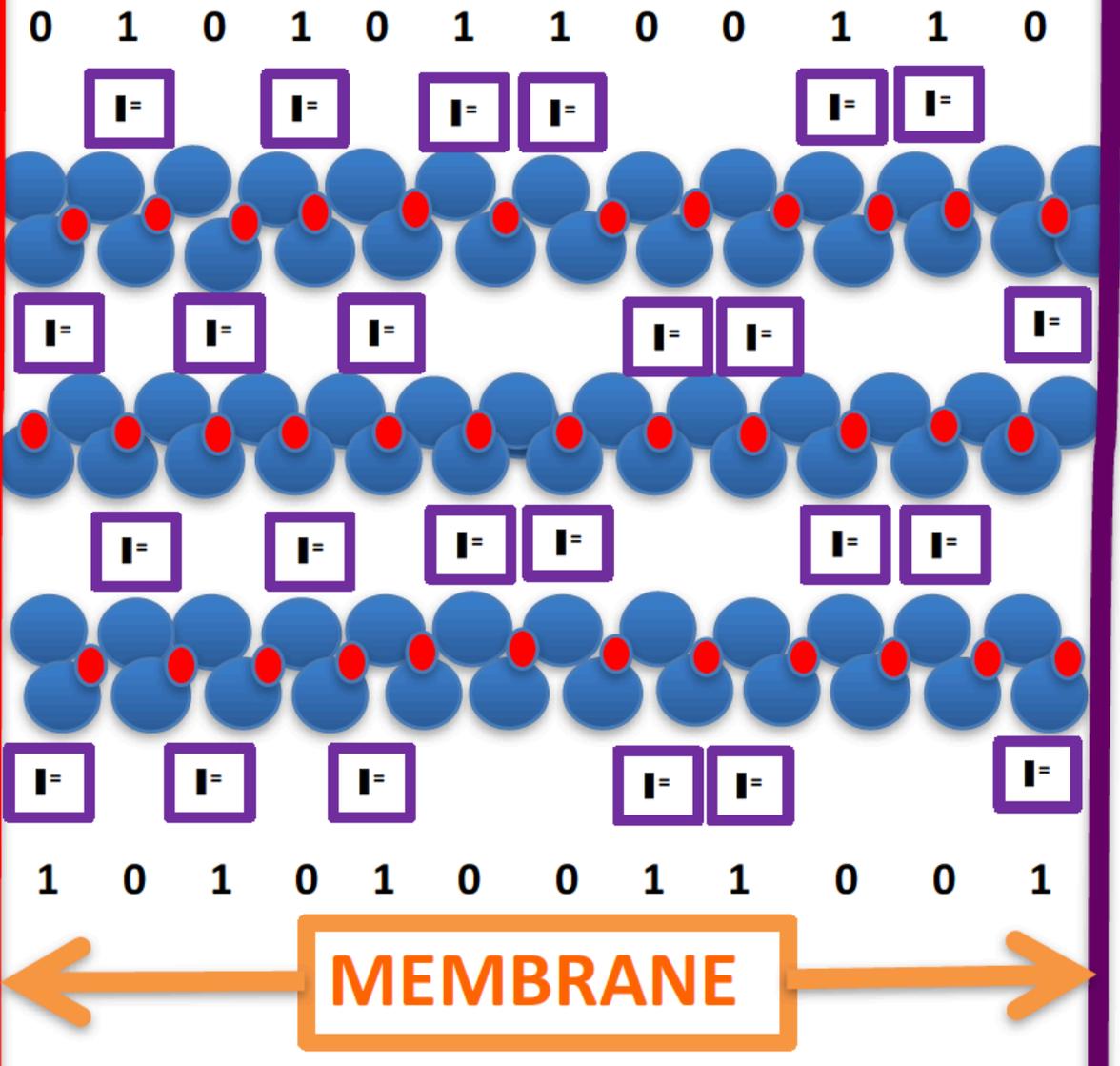


green rust as information storage and transfer system

A digital computer?

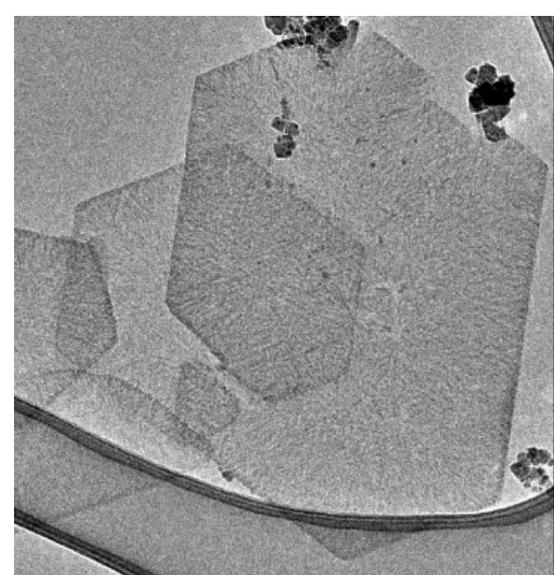
Fe^{2+} = ZERO

Fe^{3+} = ONE

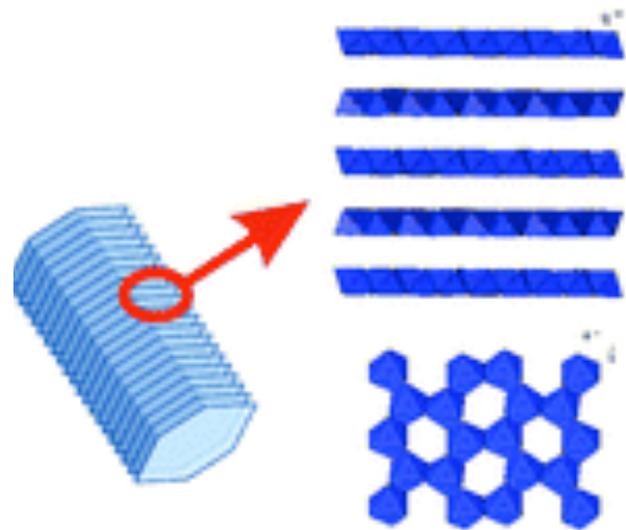


Greenwell & Coveney 2006
After Figure 6
OLEB, **36**, 13-37.

Russell & Beckett 2017
ABSCICON abstract 3192

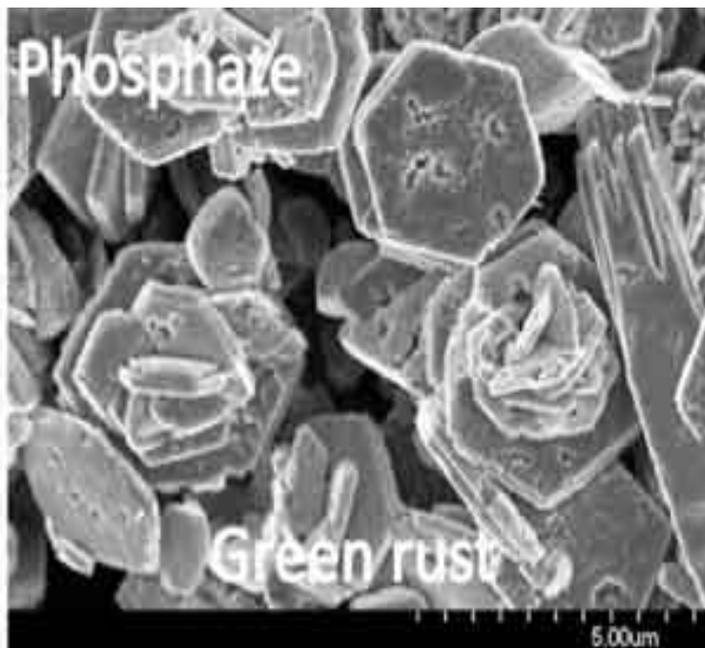


Division (?)
of screw
dislocated
(helicoidal)
GREEN RUST

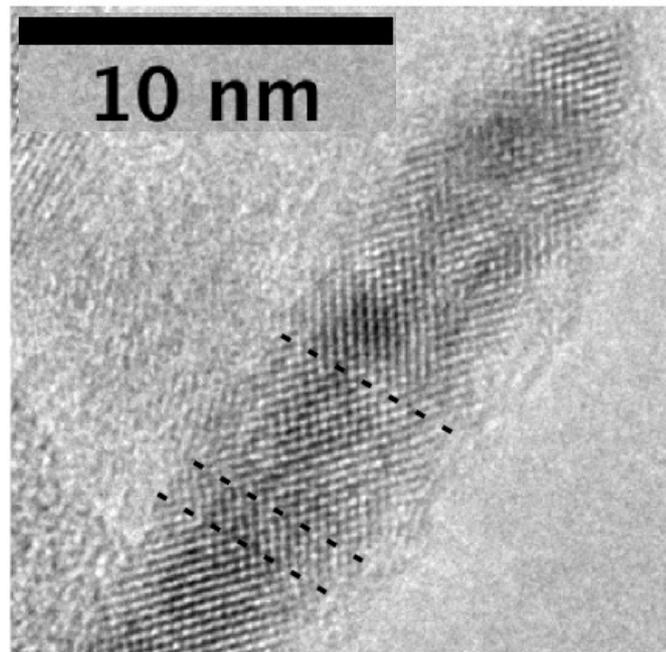


Johnson et al. 2015 *Am Min* 100:20, Fig 6k

Wang & O'Hare 2012 *J Materials Chem* 22:23064-23070

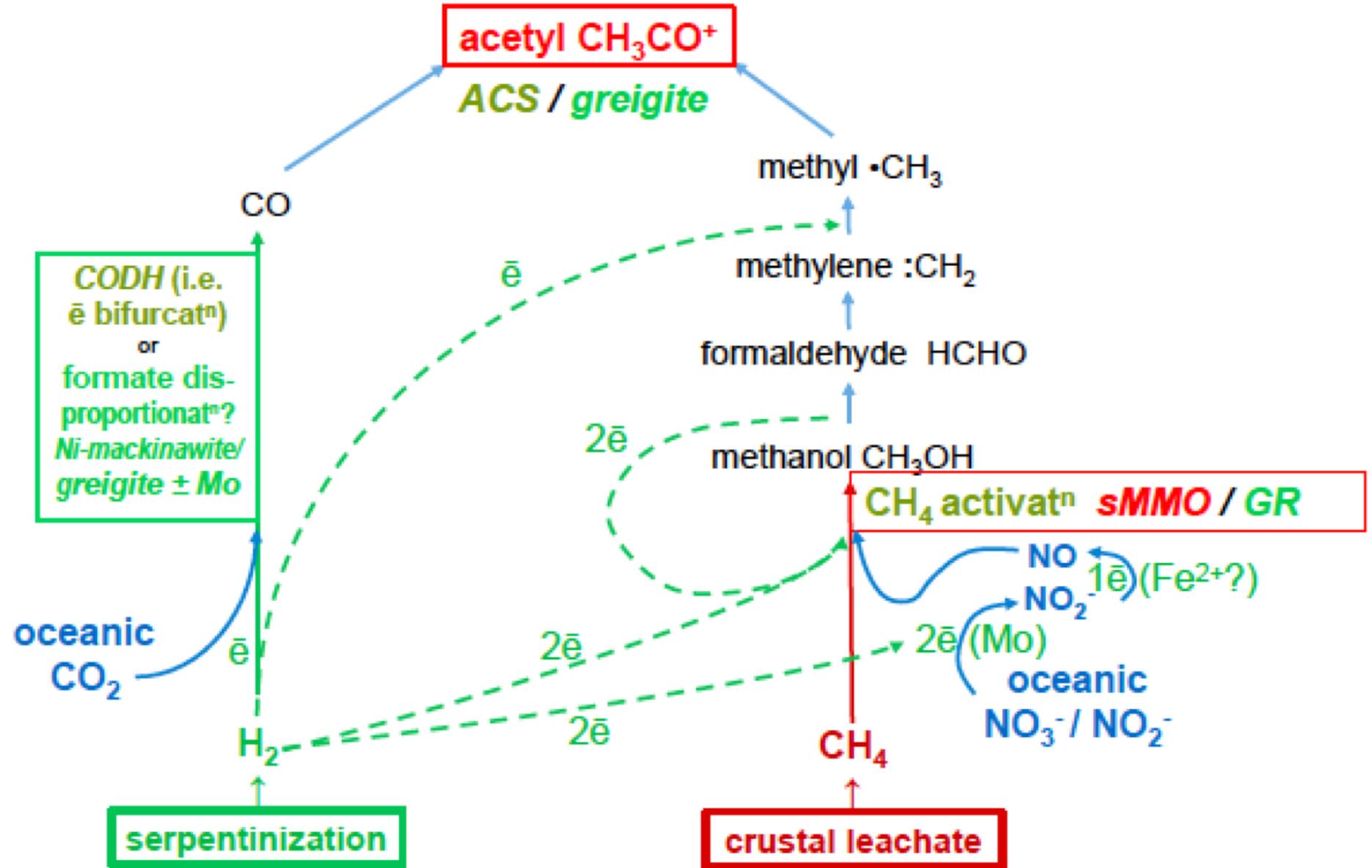


O'Loughlin et al. 2015 *Curr Inorg Chem* 5:214
Hansen & Poulsen 1999 *Clays Clay Miner* 47:312



Green rust nanorod; Johnson 2015
Am Mineralogist 100:2091-2105

Denitrifying methanotrophic acetogenesis



$\text{CO}_2 + \text{N}_2 \gg \text{NO}$ atmosphere

Carbonic ocean

$\text{pH} \sim 5.5$ $\text{Fe}^{2+} + \text{NO}_3^-$

denitrifying methanotrophic acetogenesis ?

Acetate

$\text{CO}_2 \gg \text{NO}_3^-$

H_2

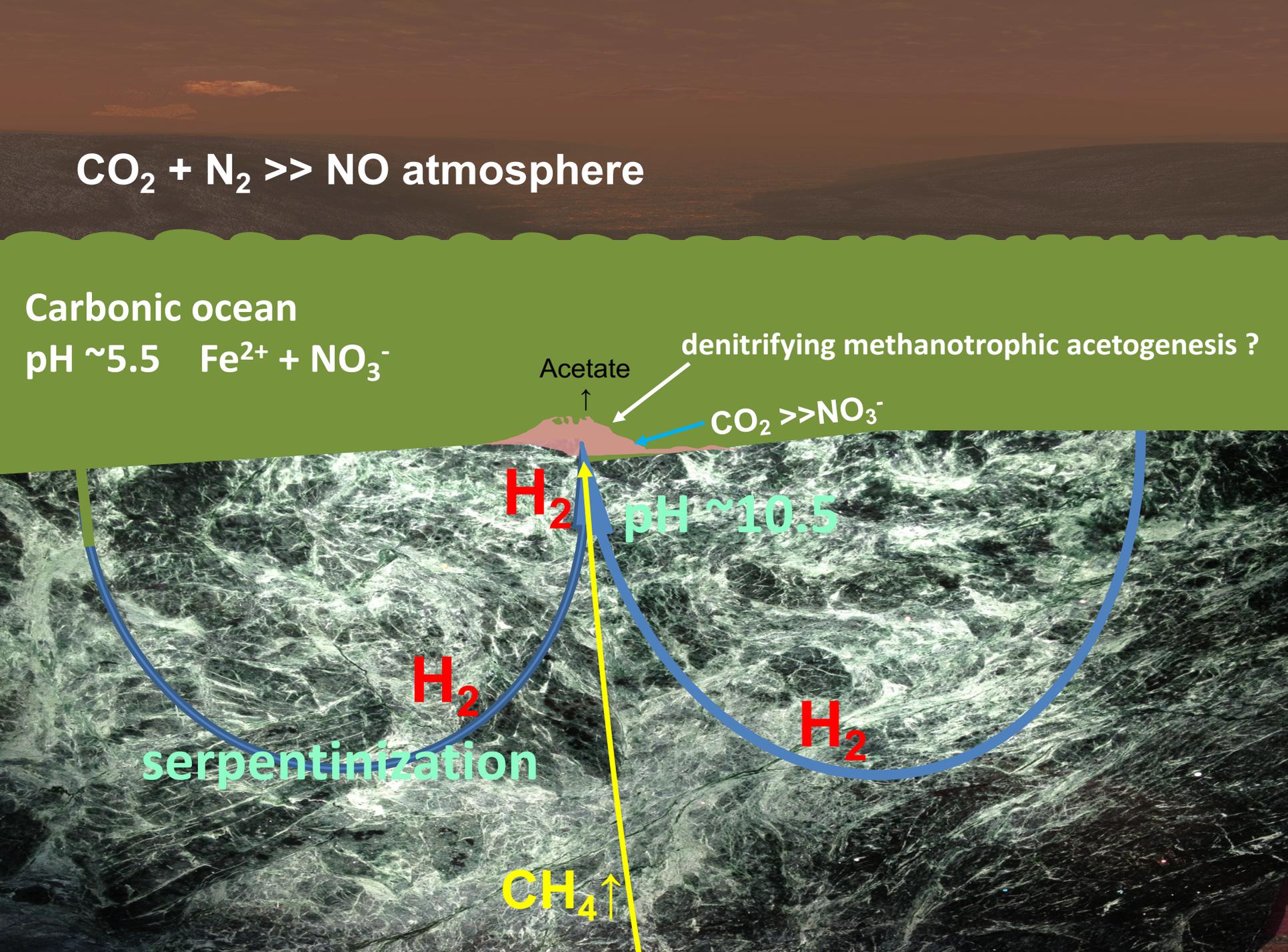
$\text{pH} \sim 10.5$

H_2

serpentinization

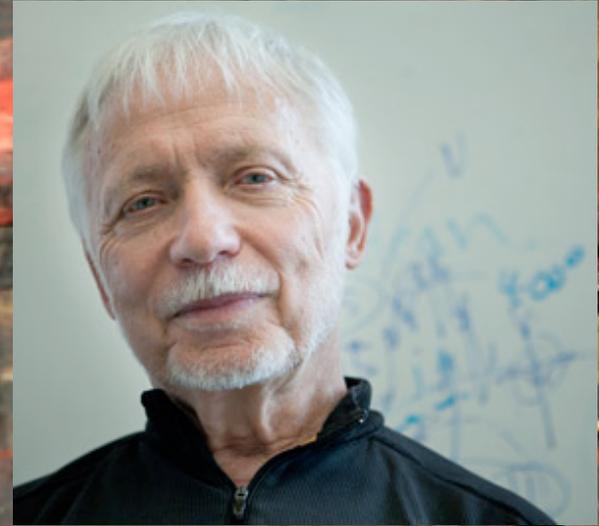
H_2

$\text{CH}_4 \uparrow$





Thanks to
Elbert Branscomb



&

Wolfgang Nitschke

