We had argued that serpentinization produced H_2 to react with CO_2 and to make CH_4 i.e., serpentinization was the sister to the first methanogens [*There are two possible outcomes (of experiments): If the result confirms the hypothesis, then you've made a measurement. If the result is contrary to the hypothesis, then you've made a discovery*. Enrico Fermi]

But we failed to make $^{13}CH_4$ in our serpentinization reactor. So biochemistry is not quicker geochemistry.

So we needed to rethink and understand how life negotiated these thermodynamic barriers

Enzymes is a physical system that is forced "uphill" which requires a coupling to a more powerful process going downhill. Enzymes are not catalysts, or not only catalysts.

Enzymes work like a turnstile, yes, you put the driving money in, but then you have work to push the turnstile around (driven reaction), only then does the money drop (the driving reaction complete) and reset the turnstile (Branscomb and Russell, 2013, 2016).

In the nano-world of the cell there is no inertia and it is the Brownian motion the ratchets the system "uphill".

Life is all about spending electrons and hydrogenating CO_2, and this should be the case on all wet and rocky planets of sufficient mass to hold an atmosphere and with enough radiogenic elements to drive mantle convection.

Electron transfer often takes place two electrons at a time. One requirement, like a turnstile, is electron bifurcation whereby one electron is driven uphill (for a reduction) while the other electron seeks out a high potential electron acceptor (e.g., O_2 or NO/NO_3^-).

So Molybedum is required as well as Fe, Ni, Co, S and P to bifurcate electrons (e.g., Russell et al., 20140.

Thus it is the inorganic elements that bring organic chemistry to life.

It is only when the serpentinizing fluids reach lakes or seas do they spontaneously precipitate iron-rich sulfides and oxyhydroxides as a pH (5 units ~300 mV) and redox (~500 mV) barrier.

The pH gradient is a natural proton motive force to drive pyrophosphate formation which in turn is used to

These are the gradients that are the ultimate drivers of life.

So fuels are H_2 and possibly/probably CH_4, and the oxidants are NO, nitrate/nitrite

Like a rocket, NO, acetate and organic scale is the entropic exhaust.

Note the first rockets had small wings, but no guidance system -- cf. metabolic engines produced autocatalytic ligand-accelerated metabolism, guidance RNA and DNA came later.

Green rust (fougerite) is the main candidate as the first protoenzyme.

As life converts a greater concentrated disequilibrium (low entropy) to lesser ones, for life detection whether dead or alive we are still looking for disequilibria (though higher entropy) --- as does the rocket. (Just the same – the it's the exhaust that drives your car).

So serpentinization is not the sister to methanogenesis but is the MOTHER engine of life.

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