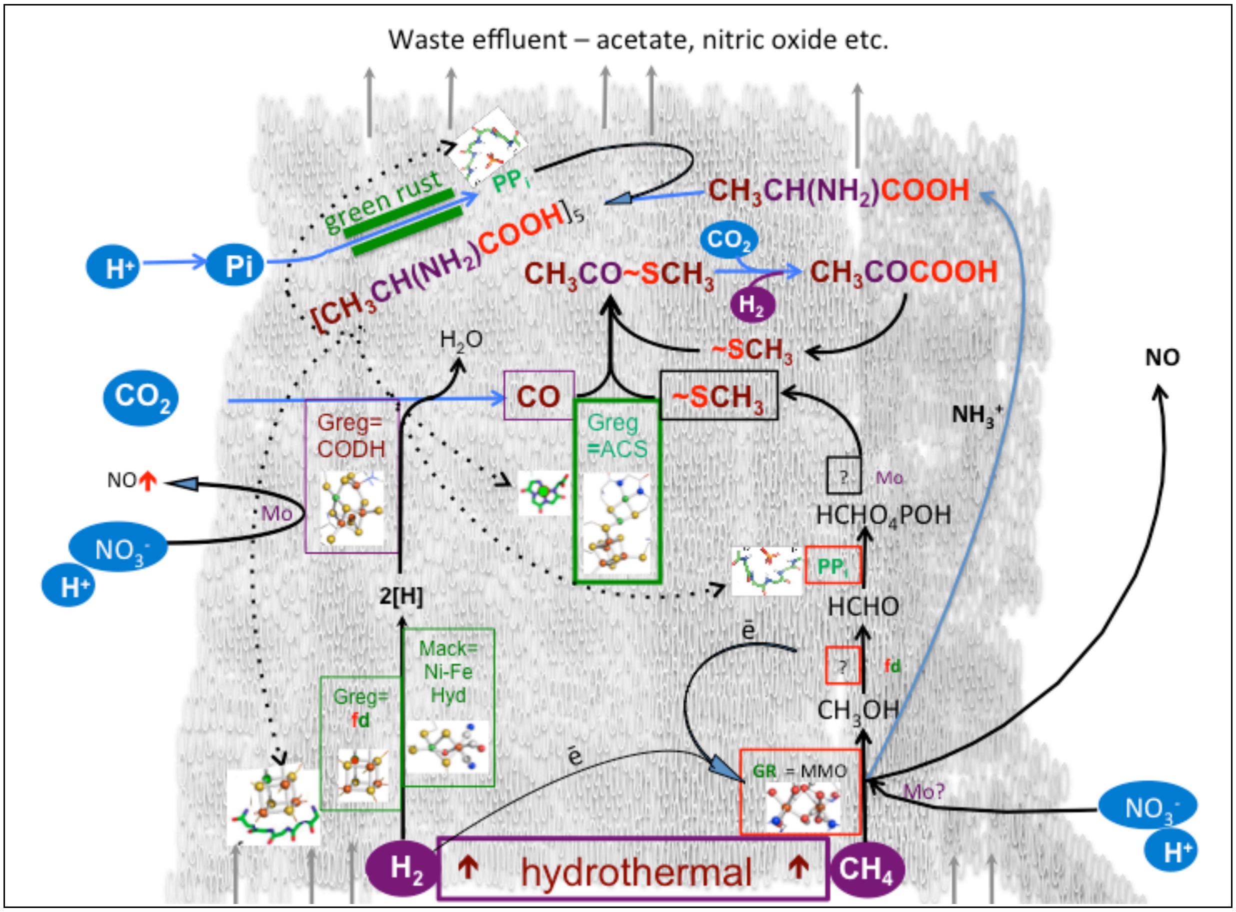
HOW THE FIRST LIGAND-ACCELERATED AUTOCATALYTIC CYCLE GAVE AN EVOLUTIONARY TRAJECTORY TO EMERGENT LIFE.

Michael J. Russell, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA.



The map figured here is intended to identify those reactions yet to be demonstrated in the lab in steps toward the first ligand-accelerated autocatalytic cycle [1,2]. It models *denitrifying methanotrophic acetogenesis* as the pathway to the emergence of life in a submarine alkaline hydrothermal mound [3]. The hypothesis was generated as a response to the extreme tardiness of CO_2 reduction to CH_4 - unachievable in the lab within 4 days [4]. In this pathway CO_2 is reduced to CO by extremely low potential Ni-Fe sulfide clusters catalyzed by Mo, while CH_4, emanating from the crust, is oxidized with NO_3^- to $-CH_3$. The two products effectively combine to produce acetate, and ammonium as a byproduct [5,6]. Carbonation and hydrogenation of acetate produces pyruvate [7]. This is aminated to alanine [8]. Alanine in turn is condensed to a 5-mer peptide on mineral surfaces in the mound [9], long enough for the backbone to sequester inorganic Fe(Ni)sulfides and pyrophosphate (PPi) clusters [10,11]. This nesting renders the clusters more stable, more catalytically active and, in the case of the sulfides, significantly reduces their redox potential. These positive feedbacks both quicken and direct the early evolution of metabolism. This is the cycle that is locked in as the foundational pathway while life complexifies and evolves. One of the missing steps along this pathway is a mechanism for converting the steep ambient proton gradient to drive a large pyrophosphate-to-orthophosphate disequilibrium. For this step we need to demonstrate that green rust can act as a proton pyrophosphatase [12,13].

References: [1] Berisford DJ 1975 *Ang Chem Int Ed Eng* 34:1059 [2] Branscomb E, Russell MJ 2013 *BBA* 1827:62 [3] Nitschke W, Russell MJ 2013 *Phil Trans R Soc B* 368:20120258 [4] White LM 2014 *UCSB Thesis* [5] Hansen HC et al. 2001 *Appl Clay Sci* 18:81 [6] Wong M et al. 2015 *Abscicon abstr* [7] Cody G et al. 2000 *Science* 289:1337 [8] Huber C, Wächtershäuser G 2003 *Tetrahed Lett* 44:1695 [9] Kawamura et al. 2011 *Astrobiol* 11:461 [10] Milner-White EJ, Russell MJ 2011 *Genes* 2 [11] Bianchi A et al. 2012 *Proteins* 80:1418 [12] Lin et al. 2012 *Nature* 484:399 [13] Barge et al. 2014 *GCA* 128:1.