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H2-promoted coevolution of minerals and C in ancient and modern rocks

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Abiotic production of molecular hydrogen (H_2) through redox-based water/rock reactions or water dissociation (e.g., water radiolysis) is now acknowledged to represent a long-lasting widespread process in the Earth's crust. In the presence of gaseous, dissolved or solid inorganic carbon, this efficient reductant can promote the formation of organic compounds through the concomitant oxidation and reduction of H_2 and carbon compounds, respectively. While water thus plays an obvious role in H_2 production, the multi-faceted role played by rock-forming minerals on reaction yields and pathways and how they further coevolve with organics and contribute to their diversification remain to be elucidated. While analogical experiments have advanced our understanding of the role of minerals as suppliers of reduced iron or catalysts in the generation of H_2 and the subsequent formation of organic compounds, we lack supporting evidence in nature. Through recent results obtained by multimodal examination at the micrometer scale of modern or ancient rocks, we will show (i) how minerals exert a local control on H_2 formation and on the type of produced carbon compounds and (ii) how minerals and organics can co-evolve and diversify through metamorphic reactions to compounds of prebiotic interest or potentially key to support the development of life (e.g., polycyclic aromatic hydrocarbons and heterocycles up to amino acids, as well as organic sulfur and phosphorus compounds). These may indeed represent outstanding resources for hydrogenotrophs and heterotrophs inhabiting the rocky subsurface which could then be able to sustainably thrive in the depths of the Earth crust without any supply of organic carbon of photosynthetic origin and in turn participate to these complex but still poorly understood dark H_2 and carbon cycles.