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Production of Geopolymerised Organic Carbon in Association with Iron at Hydrothermal Vents

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Variations in atmospheric CO_2 are regulated over two different timescales in the Earth system. On geological timescales, the amount of CO_2 in the atmosphere is regulated by the chemical weathering of silicate rocks together with the balance between the degradation and preservation of organic carbon (OC) in marine sediments. On timescales relevant to anthropogenic climate change, atmospheric CO_2 is regulated by the photosynthetic activity of marine algae and the ensuing biological pump, and again a balance between the degradation and preservation of OC, found this time in seawater, where recent work shows that a long-lived type of dissolved OC provides a reservoir for carbon, rivalling that present in the atmosphere. Over these two different timescales it is apparent that the reactivity and cycling of OC is of vital importance to the Earth system, but despite many years of research, we still do not fully understand how, or why, what is essentially labile OC can escape degradation and become preserved.

Previous work by our group demonstrates that reactive Fe species present within the marine environment acts as a catalyst for the polymerisation of simple LMW OC, into larger HMW OC via the Maillard Reaction [1]; where monosaccharides and amino acids, that are abundant in the marine environment, combine to form aromatic macromolecules termed Geopolymerised Substances (GPS), which may escape hydrolysis [2] and therefore thought to be longer lived within the ocean. It is also well known within the Food Sciences community that the rate of the Maillard reaction increases with temperature [3].

Using STXM-NEXAFS data, the work presented here suggests that the formation of GPS likely occurs within hydrothermal vent systems, where there are elevated temperatures (40 times hotter than marine pore waters) and elevated Fe concentrations (>2.5 times more concentrated than porewaters). We suggest that hydrothermal vents are a hitherto unexplored hotspot for GPS production, contributing to the long-lived DOC pool within the oceans interior.

[1] Moore et al., 2022 (https://doi.org/10.46427/gold2022.11295)

[2] Arnosti et al., 2011 (https://doi.org/10.1146/annurev-marine-120709-142731)

[3] Van Boekel, 2001 (https://doi.org/10.1002/1521-3803(20010601)45:3<150::AID-FOOD150>3.0.CO;2-9)