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Experimental evidence for abiotic organic aqueous species at high-pressure conditions

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The deep carbon cycle plays a fundamental role in Earth's dynamics, influencing processes that range from volcanic activity to microfossils, from bacterial ecosystems to the genesis of deep diamonds. Its relevance extends across multiple domains, spanning from the origin and evolution of life on Earth to climate, sustainability, and fossil fuels.

At high-pressure subsolidus conditions, carbon mobilization mainly relies on dissolution processes of carbon-bearing phases by aqueous fluids. While carbonate solubility has been extensively investigated, the contribution of reduced carbon forms, such as graphite and amorphous carbon, has been only recently taken into consideration [1], and their role in the deep carbon cycle remains poorly constrained. Several issues are still open, especially relative to the speciation and composition of the resulting COH fluid. Recent studies have suggested that organic aqueous species may serve as a previously unrecognized mechanism for carbon mobilization at depth. Thermodynamic models [2] predict the potential stability of aqueous organic solutes under certain conditions, and this hypothesis is supported by evidence from natural samples [3]. However, the extent to which these species contribute to deep carbon transport remains uncertain, as their in-situ formation conditions and stability at high pressures are still debated [4].

Here we present results from Hydrothermal Diamond Anvil Cell experiments performed to characterize the COH fluid composition in equilibrium with quartz and either graphite or glass-like carbon, at pressures up to 2 GPa and temperatures up to 800 °C. We provide experimental evidence showing the formation of aqueous organic species from the dissolution of reduced carbon in aqueous fluids at oxidizing conditions. Our results indicate that high-pressure organic compounds may play a crucial role in carbon transport and cycling at depth, with potential implications for both deep Earth geochemistry and the broader understanding of carbon fluxes in subduction zones.

[1] Tiraboschi et al (2022) *European Journal of Mineralogy* 34, 59-75 [2] Sverjensky et al. (2014) *Nature Geoscience* 2, 909-913 [3] Bouilhol et al. (2022) *Nature Communications* 13, 1-10 [4] Szlachta et al. (2022) *Geochemical Perspectives Letters* 21, 28-31