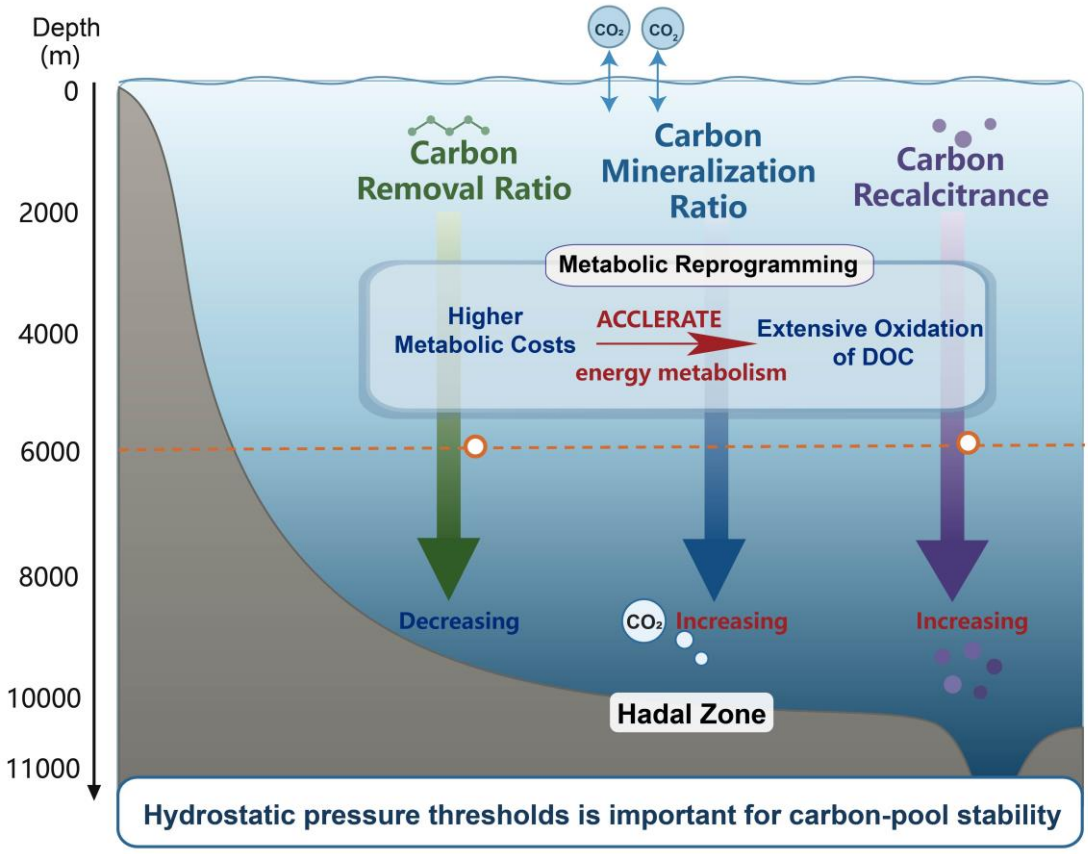
Title: From DOC Restructuring to Alkane Mineralization: How Hadal Pressure Redirects Microbial Carbon Fate

Abstract:

Hadal zones represent the deepest oceanic environments and hotspots for carbon transformation, where high hydrostatic pressure (HHP) fundamentally constrains microbial biogeochemical processes. Yet, how HHP regulates the fate of organic carbon in the hadal zones remains poorly resolved. Here, we conducted incubation experiments with pressure control under 4℃ to examine how HHP redirects microbial carbon transformation.

Natural deep-sea water from 1,800 m depth amended with the Kermadec Trench sediment microorganisms was incubated for 25 days across a full-ocean-depth pressure gradient from 0.1 to 115 MPa. Although bulk DOC concentrations showed limited net variation, FT-ICR MS revealed systematic pressure-dependent molecular restructuring. Increasing pressure was associated with higher average O/C ratios and lower modified aromaticity indices, together with pressure-dependent changes in molecular unsaturation, indicating that hydrostatic pressure altered the composition and accelerated potential persistence of extracellular DOC. Metatranscriptomic analyses further revealed that increasing pressure enhanced transcriptional investment in central carbon metabolism, particularly the tricarboxylic acid (TCA) cycle, together with stronger oxidative-stress responses, while lipid and xenobiotic metabolism were substantially reorganized. These changes indicate a pressure-driven shift toward more oxidative, respiration-oriented carbon metabolism.

Given the active alkane-degrading populations reported in hadal trench, we used *Alcanivorax xenomutans* A28 as microorganism model, isolated from 7,663.5 m in the Philippine Basin, to examine pressure-dependent carbon allocation during n-hexadecane degradation under 0.1, 40, and 80 MPa. Increasing pressure reduced overall alkane consumption, whereas the proportion of consumed carbon mineralized to dissolved inorganic carbon increased. Transcriptomic and metabolomic analyses indicated the enhanced investment in TCA cycle, especially the CO_2 producing steps

under elevated pressure.

Together, these results demonstrate that HHP simultaneously constrains the rate of organic carbon utilization and alters its transformation efficiency, reducing DOC removal while increasing the fraction of consumed carbon mineralized and promoting the formation of more persistent residual DOC. These further suggest that assessments of deep-ocean carbon-pool stability should explicitly consider depth-dependent pressure thresholds.