Prospects for an archaeal lipid paleobarometer

ANN PEARSON[1*], SARAH J. HURLEY[2], FELIX J. ELLING[1], ELISE B. WILKES[3], HILARY G. CLOSE[4]

[1] Department of Earth and Planetary Sciences, Harvard University, Cambridge, Massachusetts, USA (*pearson@eps.harvard.edu)
[2]Department of Geological Sciences, University of Colorado Boulder, Boulder, Colorado, USA
[3]Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, California, USA
[4]Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, Florida, USA

Understanding the relationship between Earth's temperature and atmospheric carbon dioxide (CO_2) concentration is essential to climate research. All estimates of pCO_2 from >1 Ma rely on proxy reconstructions, each with different uncertainties and underlying assumptions. Despite efforts to expand the types of geologic samples these proxies are based on, there is no consensus about the most accurate history of Cenozoic pCO_2 [1]. Recently we proposed a proxy based on archaeal lipids, ε_{Ar} [2, 3]. Like the phytoplankton proxy ε_P, ε_{Ar} is based on lipids recovered from marine sediments; ε_{Ar} represents the carbon isotopic difference between seawater HCO_3^- and crenarchaeol, a product of Thaumarchaeota ($\varepsilon_{Ar} = \delta^{13}C_{HCO3} - \delta^{13}C_{cren}$). The proxy rationale is derived from empirical field observations [2] and from a corroborating theoretical model [3]. In the marine water column, ε_{Ar} correlates significantly with all measures of respiration intensity, including increased CO_2 and NO_3^- concentrations and decreased O_2. In contrast to ε_P, values of ε_{Ar} become larger at low $CO_{2(aq)}$ [2]. Because Thaumarchaeota use the bicarbonate-requiring 3-hydroxypropionate/4-hydroxybutyrate (3HP/4HB) pathway of carbon fixation, we proposed that they are dependent on CO_2 diffusion, followed by intracellular catalysis to HCO_3^-. Thus, ε_{Ar} should be a function of both $CO_{2(aq)}$ and growth rate [3]. We will discuss the resulting prospects and limitations for paleobarometry, including its likely useful range (200 – 1500 ppm pCO_2) and sources of uncertainty.

[1] Beerling DJ, Royer DL (2011) Convergent Cenozoic CO_2 history. *Nature Geoscience* 4, 418-420. [2] Hurley, S.J., et al. (2019) CO_2-dependent carbon isotope fractionation in Archaea, Part II: Natural marine planktonic populations. *GCA*, in review. [3] Pearson A, et al. (2019) CO_2-dependent carbon isotope fractionation in Archaea, Part I: Modeling the 3HP/4HB pathway. *GCA*, in review.