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A stable isotopic investigation of chemosymbiosis through geological time

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Biomineralizing organisms use organic templates during shell formation, and this shell-bound organic matter (SBOM) records the isotopic composition of an animal's diet [1]. By analysing the stable isotopic signature of SBOM the nutritional strategies of fossil bivalves and brachiopods can potentially be directly reconstructed. We have used carbon, nitrogen and sulphur values to investigate the occurrence of chemosymbiosis through geological time. Chemosymbiosis is an unusual nutritional strategy whereby invertebrate animals obtain their nutrition from symbiotic bacteria, that oxidize sulphur (thiotrophy), methane (methanotrophy) or both (dual symbiosis). This allows bivalves to thrive in inhospitable ecosystems of the deep sea such as cold seeps and hydrothermal vents., However, whether or not ancient seep dwellers were chemosymbiotic is currently unknown.

Methanotrophic and dual symbiotic invertebrates use ^{13}C-depleted methane as a carbon source. Therefore the δ^{13}C values of SBOM in modern specimens distinguish these nutritional strategies (at cold seep environments: -64.4 to -36.3‰ $\bar{x}$=-53.3‰ n=15 individual specimens) from thiotrophy (cold seeps: -37.1 to -25.1‰ $\bar{x}$=-31.5, n=49 / reducing environments: -28.6 to -21.6‰ $\bar{x}$=-25.5, n=14) and heterotrophic bivalves (all environments: -26.3 to -16.0, $\bar{x}$=-20.9, n=47). Similar values were found in subfossil (< 50ka) suspected thiotrophic seep clams (- 33.1 to -27.9, $\bar{x}$=30.3, n=9). δ^{34}S values of modern thiotrophic bivalves (-12.3 to -2.5‰ $\bar{x}$=-6.5; n=10) are distinct from heterotrophic species (-1.4 to +11.9‰ $\bar{x}$=+3.8, n=20), due to their use of depleted sulphide. SBOM δ^{15}N is generally lighter for modern chemosymbiotic taxa (-2.7 to +7.2, $\bar{x}$=+2.6, n=15) than heterotrophic specimens (+5.6 to +14.1‰ $\bar{x}$=+10.4, n=21).

SBOM was successfully isolated from fossil bivalves, and preliminary results from Pleistocene to Cretaceous seep specimens allow positive identification of thiotrophy in lucinid and vesicomyid clams (δ^{15}N = 2.3 to 5.6‰ $\bar{x}$=4.3, n=4 / δ^{34}S= -13.0, to -1.5‰ $\bar{x}$=-5.0, n=8), when compared to isotopic nutritional ranges of modern SBOM. Bathymodiolid mussels from Miocene seeps were found to have carbon values reflecting a chemosymbiotic lifestyle (δ^{13}C = -31.1 to -29.5‰, $\bar{x}$=-30.4, n=3), that are more depleted than fossil suspected heterotrophic bivalves (-27.7 to -22.9‰ $\bar{x}$=-26.0, n=16), and similar to subfossil seep mussels (-33.9 to -29.2, $\bar{x}$=-31.6, n=4).

Data will be presented for more ancient seep specimens, including pre-Cretaceous extinct bivalve taxa and monospecific brachiopod assemblages. This will test the possibility of chemosymbiosis in seep dwelling brachiopods that disappeared from cold seeps after taxonomic domination in the Palaeozoic and Mesozoic.

[1] Dreier et al., FEMS Microbiol Ecol, 2012, 81: p. 480-493.