

Chemosymbiotic relationship in Ediacaran Tubular Animals

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The terminal Ediacaran epoch marked the proliferation of delicate tubular lifeforms, providing critical insights into early metazoan evolution. Clarifying the nutritional mechanisms of these pioneer organisms remains pivotal for reconstructing ecological dynamics in ancient marine ecosystems. Current debates center on interpreting their survival strategies in sulfidic environments. Our investigation of exceptionally preserved *Conotubus* specimens through multiple geochemical evidence reveals a novel chemotrophic adaptation pattern. Multi-sulfur isotope systematics ($\delta^{34}\text{S}$, $\Delta^{33}\text{S}$) combined with high-resolution in situ sulfur isotope mapping demonstrate these organisms thrived at redox transition zones where sulfide oxidation coupled with microbial sulfate recycling generated steep chemical gradients. Crucially, the detected molybdenum isotope anomalies ($\delta^{98}\text{Mo} = -1.4\%$ to -2.7%) mirror metabolic fractionation patterns in contemporary vent-dwelling tubular animals, indicating analogous enzymatic processes mediated by bacterial symbionts. We establish that Ediacaran tubicolous fauna utilized chemolithoautotrophic partnerships to exploit fluctuating redox conditions, effectively detoxifying sulfides while securing energy resources. This symbiotic innovation not only enabled niche expansion across oxygen-deficient seafloors but also potentiated the functional diversification of complex life prior to the Cambrian radiation.