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BIOMETARCHIVE –GEOMICROBIOLOGY OF THE 1 MA SEDIMENTARY ARCHIVE OF FERRUGINOUS LAKE TOWUTI, INDONESIA.

Lake Towuti, Indonesia, is an oligomictic system that has undergone significant changes in trophic state and redox conditions since the Mid-Pleistocene. Tropical weathering of lateritic soils supplies the lake with high iron inflows but minimal sulfate, resulting in anoxic ferruginous conditions below 130 m water depth. These conditions make Lake Towuti a suitable analogue for Archean and Proterozoic oceans.

In 2015, the International Continental Scientific Drilling Program (ICDP) recovered a 113-m-long sediment core as part of the Towuti Drilling Project. This core, covering approximately 1 million years of depositional history, was dedicated to geomicrobiological investigations. A contamination tracer was added to the drilling fluid to identify uncontaminated core sections, ensuring the integrity of the samples. The project BioMetArchive aims to provide a complete characterization of the lacustrine subsurface biosphere through taxonomic and metagenomic analysis, complemented by environmental and geochemical datasets. This includes identifying the prime microorganisms involved in iron mineralization and organic matter (OM) remineralization under ferruginous conditions to shed light on the biogeochemical processes that shape Lake Towuti's unique subsurface ecosystem, and transpose these findings to Earth's ancient oceans.

Geochemical analyses showed that water column stratification in Lake Towuti leads to a depletion in terminal electron acceptors (O2, Fe3+, SO42-), just below the sediment-water interface. This resulted in a significant decrease in cell counts (109 to 104 cells × cm^{-3}) and a shift in microbial community composition marked by a transition from sulfate-reducing bacteria (SRB) to fermentative archaea represented by uncultivated clades of Bathyarchaeia. Metabolic features attributed to this class include sulfur transformation and acetogenic fermentation. 16S rRNA gene profiling of microbial populations revealed a drastic decrease in taxonomic diversity inherent to substrate depletion during shallow burial, whereas increased compositional variability in SRB populations was observed in the vicinity of tephra layers and diatom oozes. Microbial alpha and beta diversity also varied with different lithologies across stratigraphic units. Unit 1a, making up the upper 20 m below lake floor (mblf), shelters an active and diverse microbial community, essentially composed of Bathyarchaeia, Hadarchaeota, Acidobacteriota, and Chloroflexota, involved in OM remineralization, as shown by the effective turnover of volatile fatty acids and other solutes in the pore water. Unit 1b, i.e. 20 to 70 mblf, harbours a deep biosphere community adapted to a nutrient-depleted environment, with the relative abundance of Bathyarchaeia exceeding 70%. The lowermost unit 1c, i.e. 70 to 100 mblf, is characterized by deltaic inflows and displays an increased microbial diversity, with Proteobacteria and Actinobacteria as terrestrial elements remobilized from the catchment, alongside dominant Bathyarchaeia.

Thus, variations in 16S rRNA gene assemblages reveal that microbial diversity and composition are closely related to the depositional history of Lake Towuti across the different stratigraphic layers. We conclude that dynamic shifts in Lake Towuti's depositional conditions are tractable in the taxonomic and functional diversity of the subsurface biosphere. During burial, sediment substrate depletion actively selects for acetogenic Bathyarchaeia, highlighting their adaptability and persistence as prime constituents of microbial life in deep sediments.

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