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Biogeochemistry of an Fe- and Mn-rich stratified lake: Tasik Biru (Blue Lake) in Borneo, Malaysia, as a modern model habitat for the ancient ocean

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Tasik Biru is a ~70 m-deep tropical lake in Borneo, Malaysia, originating from a water-filled open pit mine. Here, we investigate the biogeochemistry and microbial community of the lake as a modern model habitat to the stratified ancient ocean. Data from our 2024 field campaign, in conjunction with an earlier dataset from 2003-2004 [1] indicate that the lake has been stably stratified for at least 20 years. A sharp chemocline exists at around 50 m depth, marked by a depletion of O_2 and a decrease of pH from 7 to 5 in the anoxic bottom water. While the lake is relatively rich in sulfate (~300 µM), only a fraction of the sulfate is microbially reduced, leading to a slight decrease to ~240 µM and a modest increase of dissolved sulfide to 4 µM. In comparison, dissolved Fe^{2+} and total Mn rise to 50-200 µM in the anoxic layer, with an unusual 1:1 molar ratio in their concentrations. Depth profiles of other nutrients (PO_4^{3-}, Si) and trace metals (As, Mo, Sb, Co, U, V) increase or decrease across the chemocline, indicating major controls via cycling of redox-sensitive elements. Microbial 16S community analysis reflects various metabolisms occurring in the lake, from core aerobic metabolisms in the oxic layer, to putative nitrite-dependent methane oxidation (e.g., by *Methylomirabilis*) at the chemocline, to sulfate reduction, methanogenesis and fermentation in the anoxic layer. Commonly known iron- and manganese-cycling microorganisms were not identifiable, indicative of Fe-Mn cycling by new microbial groups or via coupling to sulfur biogeochemistry. Tasik Biru's anoxic water has Fe, Mn, and H_2S concentrations that straddle the corresponding ranges currently believed for the Archean and Proterozoic oceans, perhaps lending it as a model habitat for the transitory period near the Great Oxidation Event. Overall, our study is the first exploration of an Fe- and Mn-rich stratified tropical lake, with a complete dataset on trace metals across depths, that could serve as a model habitat for the Precambrian oceans.

[1] Sari, Ujang, Ahmad (2006), *Water Sci Tech* 54, 289-299.