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Linking landscape history to biogeography in the Transantarctic Mountains, Antarctica: a geochemical perspective - *F.W. Clarke Award Lecture*

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Ice-free regions of the Transantarctic Mountains (TAM) and McMurdo Dry Valleys (MDVs) form one of Earth's most extreme ecosystems, where water availability, salt accumulation, and landscape stability collectively define the limits of life. Across the region, soil geochemistry records the history of atmospheric deposition, glacial advance and retreat, aeolian redistribution, and meltwater events. We synthesized geochemical datasets from the central TAM and the MDVs to demonstrate how landscape history governs salt and nutrient cycling, and in turn informs invertebrate and microbial biogeography.

Water-soluble salts in TAM soils span many orders of magnitude (from <10 to >80,000 μg g^{-1}), with strong elevation and inland gradients reflecting prolonged exposure, minimal flushing, and atmospheric nitrate and sulfate accumulation. Coupled meteoric ^{10}Be–NO_3^- relationships reveal exposure ages from post-LGM surfaces to multi-Myr stable landscapes, linking geochemistry to surface stability and wetting duration. In the MDV, aeolian transport, ephemeral stream flow, and episodic brine formation redistribute salts and nutrients across valley floors and into closed-basin lakes, creating weathering gradients. Similar processes appear to have operated in the TAM, but over longer exposure timescales and with reduced hydrologic connectivity. Across both regions, total soluble salt concentration, N:P ratios, and perchlorate abundance correlate with microbial detectability and diversity.

Our results indicate that Antarctic soil biogeography is fundamentally tied to landscape history, where surface exposure age, hydrologic connectivity, and atmospheric deposition control salt and nutrient inventories. By linking geomorphic evolution to habitability, our work demonstrates how polar desert landscapes serve as natural laboratories for understanding life at environmental limits on Earth and potentially on other cold, arid moons and planets.