# An early Neoproterozoic dynamic sulphur cycle: evidence from the Shaler Supergroup

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**Abstract:**

The Neoproterozoic (1000-542Ma) is a dynamic era of Earth history, punctuated by super continental break-up, global glaciations, and the evolution of metazoan life [1,2,3]. During the early to mid-Neoproterozoic, Earth's redox budget was in a state of flux, the evidence for which is preserved in the isotopic records of sulphur and carbon [4]. In order to constrain the initiation of this dynamic behaviour, we described and sampled 3 outcrop stratigraphic sections and a drill core at ~3m intervals through the Minto Inlet Formation of the Shaler Supergroup, which is exposed in the Minto Inlier of NW Victoria Island, NWT.

The Minto Inlet Formation is >250m thick and hosts well-preserved Neoproterozoic sulphate-rich evaporites deposited in a periodically restricted intra-continental marine basin. The Minto Inlet Formation was deposited between ~900Ma and ~800Ma based on detrital zircon geochronology and stratigraphic correlation with well-calibrated sections in the northern Cordillera [4]. We measured multiple sulphur isotopes ($\delta^{34}S$, $\Delta^{33}S$) of the sulphate fraction in all of the stratigraphically controlled dataset of 67 samples.

Current understanding of the sulphur isotope record suggests that the fraction of S buried as pyrite relative to sulphate evaporites was high, approaching 1 for most of the Proterozoic, through the Ediacaran, and into the early Phanerozoic [5]. We used multiple sulphur isotope measurements of Minto Inlet Formation evaporites to constrain models of S fluxes into and out of the ocean prior to the onset of the Cryogenian (720-635Ma). This approach suggests that the relative burial fraction of S as pyrite was extremely low (≈0.2) during the earliest stages of the deposition of the Minto Inlet Formation. Previously, pyrite burial fractions this low had been recorded only at Permian-Triassic time, more than ≈600 Ma after the deposition of the Minto Inlet Formation [5]. Our results indicate large scale variations in ocean redox conditions and a dynamic sulphur-cycle were initiated during the early-Neoproterozoic.

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# Earths Icy Biosphere as a Model for the Microbiology of Other Icy Worlds

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Antarctic terrestrial environments were initially thought to be devoid of life. However, discoveries of microbial life in Antarctic lake ice, and within and under Antarctic glacial ice have all provided information on the diversity and biogeochemical importance of biology to icy environments. We now know that polar microbiology plays a major role in biogeochemical processes on Earth and offers new insights into the evolution and biodiversity of life on our planet. The discovery of viable microorganisms in icy environments has extended what we know about the limits of life on Earth and provides strong evidence to show that life has successfully radiated into virtually all habitats on our planet containing "free" liquid water. Icy worlds beyond Earth may harbor the greatest volume of habitable space in the Solar System. For at least five of these worlds, considerable evidence exists to support the conclusion that oceans or seas may lie beneath the icy surfaces. The total liquid water reservoir within these worlds may be some 30 to 40 times the volume of liquid water on Earth. For example, data obtained from orbiters have revealed a deep ocean of liquid water beneath a thick chaotic ice cover on Europa where organic matter derived from comets and oxidants provided by radiation from Jupiter's magnetosphere may yield a habitat for life and a reservoir of endogenous and exogenous substances. This vast quantity of liquid water begs the question: Can life emerge and thrive within ice and the cold, lightless oceans beneath many kilometers of ice? To address this broad question, information on water activity, metabolic energy sources, nutrient availability, the ability of the physical environment to support growth and reproduction, and the origin of the biological seed must be known. Studies of Earth's subzero environments will continue to play a crucial role in informing our understanding of habitability on other frozen worlds in our Solar System and guide our development of the robotic tools needed to investigate those distant environments. We will present combined laboratory, numerical, analytical, and field investigations from Earth's polar regions to define the potential habitability of icy worlds beyond Earth.