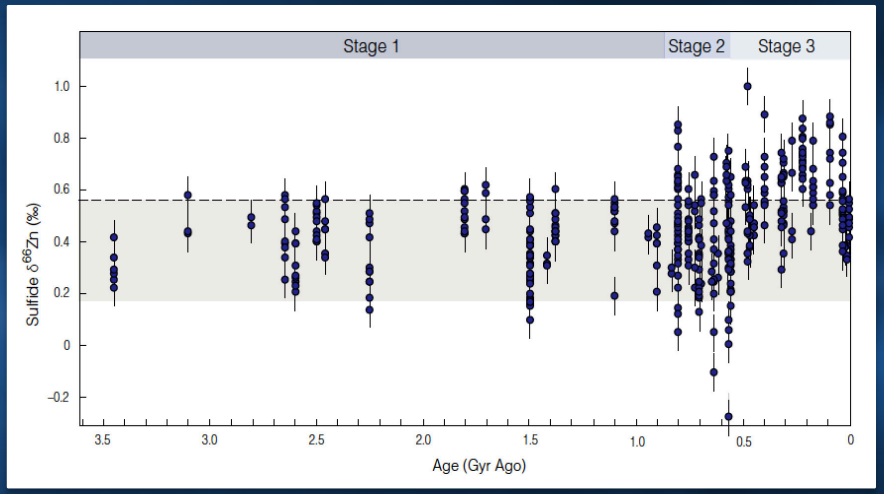
Tracking the Rise of Eukaryotes with Zinc Isotopes

Eukaryotes are organisms whose cells have a nucleus enclosed within membranes, unlike prokaryotes (Bacteria and other Archaea). Eukaryotes gave rise to all higher life on Earth. This first-ever long-term record of sedimentary zinc (Zn) isotopes reveals a fundamental shift in the marine Zn cycle ~800 million years ago, which likely marks a transition to more eukaryote-rich marine ecosystems in phase with independent evidence for a dramatic rise in biospheric oxygen.



SEDIMENTARY ZINC ISOTOPE RECORD SPANNING 3.5 BILLION YEARS.
New data from the sulfide fractions of sulfide-rich black shales, such as this outcrop on Baffin Island, Canada (top), fall into three stages. Stage 2 is a transition interval during which $\delta^{66}Zn$ values distinctively lighter and heavier than the crustal range are expressed, likely reflecting both the ecological rise of eukaryotes and re-organization of the global biogeochemical Zn cycle.

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INNOVATION | Stable isotopes of Zn have the potential to track the rise and ecological expansion of eukaryotes in the oceans. Modern eukaryotic phytoplankton have elevated Zn demands relative to cyanbacteria, and our analyses with updated genomic databases suggest that Zn is often the most essential inorganic cofactor in eukaryotic enzymes across all lineages.

DISCOVERY | The best explanation for the observed rise in $\delta^{66}Zn$ in pyritic marine shales (left) is an increase in organic-derived Zn burial. This increase was likely caused by both a higher Zn demand following the rise of eukaryotes to ecological dominance in phase with an overall increase in total global productivity. Given that the oldest eukaryotic microfossils are ~1.7 billion years old, the zinc record suggests a billion-year lag between eukaryotes' emergence and their rise to prominence.

RELEVANCE | The Zn record provides an opportunity to evaluate the impact that the first abundant eukaryotic productivity may have had on climatic and carbon cycle perturbations at a critical point in the history of life on Earth, not long before the first appearance of animals.