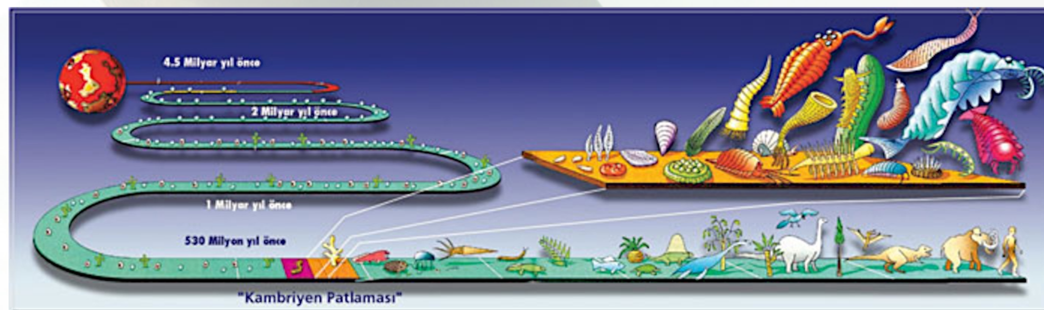
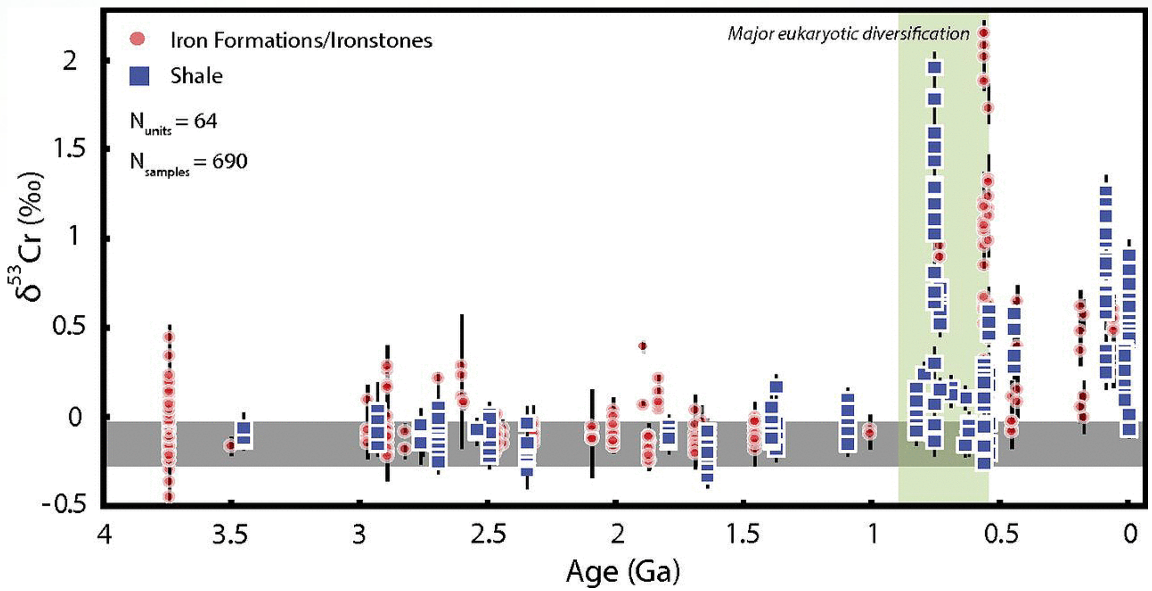
Rise in Earths Oxygen Timed to the Rise of Animals

An evolutionary burst 540 million years ago filled planet Earth with an astonishing diversity of animals, that some researchers believe was the result of a rise in atmospheric oxygen.

The chromium (Cr) isotope method provides a way to track atmospheric O_2 based on the assumption that marine sediments capture the signal of oxygen-dependent Cr cycling in ancient soils, and new data demonstrates that oxygen was low enough during the long period prior to this increase in animal diversity (the mid-Proterozoic) to have directly hindered the emergence of advanced animals until approximately 800 million years ago.

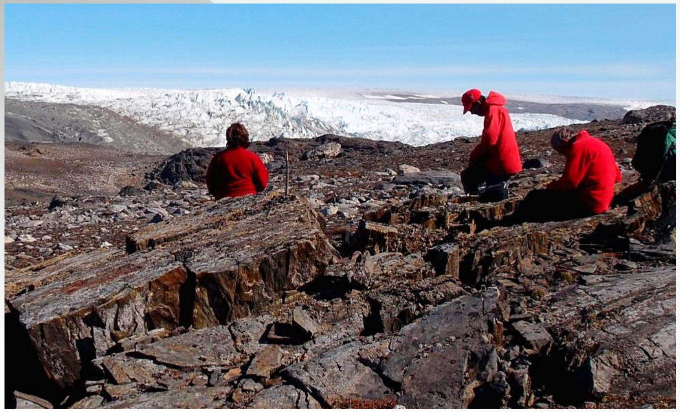
This now helps explain the mysterious, billion-year lag between the first appearance of eukaryotes (life consisting of cells with a distinct nucleus) and the emergence of complex animals on Earth.





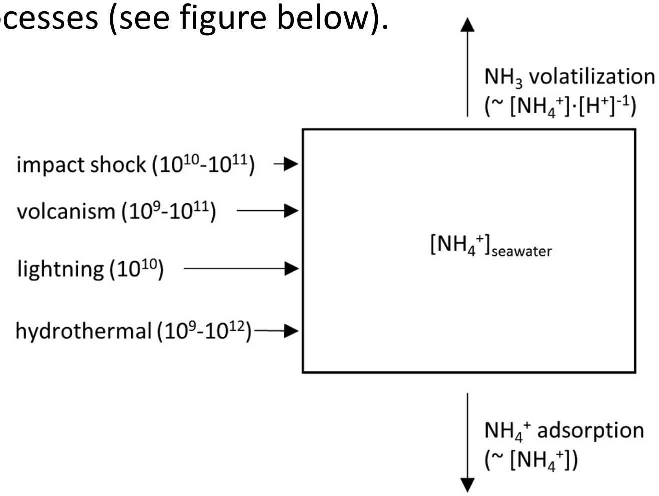
A shale-hosted Cr isotope record of low atmospheric oxygen during the Proterozoic. **Devon B. Cole**, **Christopher T. Reinhard**, Xiangli Wang, Bleuenn Gueguen, Galen P. Halverson, Timothy Gibson, Malcolm S.W. Hodgskiss, N. Ryan McKenzie, **Timothy W. Lyons** and Noah J. Planavsky. *Geology*. June 2016. *doi: 10.1130/G37787.1*

Nitrogen in Ancient Mud: A Biosignature?



BACKGROUND: Nitrogen is an essential nutrient for all life on Earth and possibly elsewhere. Some organisms are capable of converting nitrogen gas into molecules that other species can use. Nitrogen fixation, as the process is called, involves breaking the powerful chemical bonds that hold nitrogen atoms in pairs in the atmosphere and using the resulting single nitrogen atoms to create molecules such as ammonia, which is a building block of many complex organic molecules, such as proteins, DNA and RNA. Nitrogen enrichments in ancient sedimentary rocks or in extraterrestrial samples, therefore, may be a useful biosignature.

THE RESEARCH: This study focused on 3.8 billion-year-old rocks from the Isua Supracrustal Belt in Greenland, where nitrogen enrichments of up to 430 ppm were found. While this may be a biosignature, abiotic processes such as lightning or volcanism can also fix atmospheric N_2 and contribute to sedimentary nitrogen burial in the absence of life. A numerical model was developed to determine how much nitrogen enrichment could occur through only abiotic processes (see figure below).



TAKE-HOME: Results showed that abiotic processes alone could not explain the nitrogen levels seen in the Isua rocks. As such, the results provide more evidence of an early origin of life on Earth—before 3.8 billion years ago. This research also suggests that analyzing nitrogen levels could help detect signs of life on Mars or perhaps elsewhere in our Solar System.

Stüeken, E.E., 2016. Nitrogen in Ancient Mud: A Biosignature? *Astrobiology*, *16*(9), pp.730-735.

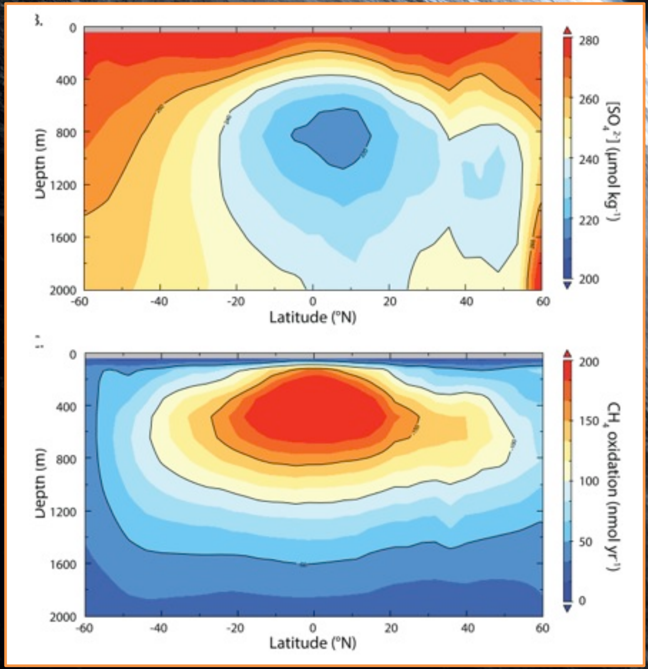
METHANE MUTED

How Did Early Earth Stay Warm?

The Alternative Earths Team of the NASA Astrobiology Institute finds that, contrary to popular climate models for the distant past, methane could not be the gas that kept the oceans liquid and livable.

For at least a billion years of its early history, planet Earth should have been frozen over but wasn't. The sun was up to 20% dimmer than it is today—too weak to warm the planet on its own. Historical computer models of the Earth's atmosphere have indicated that methane, a potent greenhouse gas, was the primary climate warming agent for the first 3.5 billion years of Earth history because oxygen was absent initially and little more than a whiff later on. (Nowadays oxygen is one-fifth of the air we breathe, and it destroys methane in a matter of years.)

PNAS, Sept. 26, 2016



DISCOVERY | A new accounting of biogeochemical cycles in the oceans reveals that methane, which is produced in the oceans by specialized microbes that ferment organic matter, has a much more powerful foe than oxygen: sulfate. Between 1.8 billion and 800 million years ago, seawater sulfate limited both the production and accumulation of methane to only 1 to 10 parts per million (ppm) in the atmosphere. That's a fraction of the 300 ppm touted by some previous models *and well below remote detection limits of current technology*.

INNOVATION | The numerical model used in this study, which calculated sulfate reduction (*top*), methane oxidation (*bottom*), and an array of other biogeochemical cycles for nearly 15,000 three-dimensional regions of the ocean, is by far the highest resolution biogeochemical model ever applied to the ancient Earth. Previous models used no more than five regions.

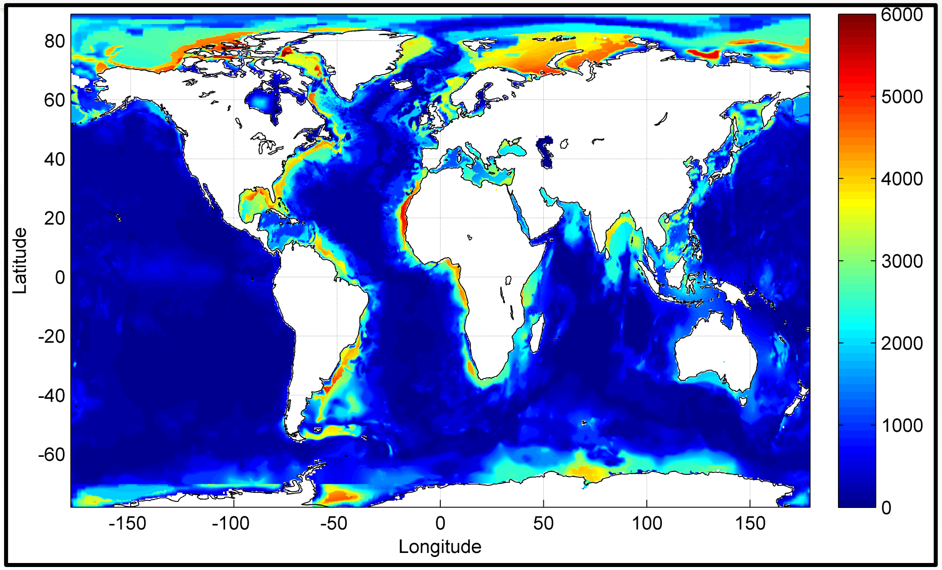
IMPACT | Astrobiologists now face a serious challenge to explain our planet's early habitability. Identifying early Earth's precise greenhouse cocktail, probably including water vapor, nitrous oxide, and carbon dioxide, is essential for spectroscopic efforts to assess the habitability of other planets in our galaxy.

BACKGROUND IMAGE | This artist's depiction of an ice-covered planet in a distant solar system resembles what early Earth might have looked like if a mysterious mix of greenhouse gases had not warmed the climate. **CREDIT: EUROPEAN SOUTHERN OBSERVATORY (ESO) VIA WIKIMEDIA COMMONS**

Thermal Habitability of the Earth's Seafloor

BACKGROUND: Approximately 70% of the Earth's surface is covered by ocean—on average, under 3,700 m of water. At the seafloor is a blanket of unconsolidated sediment consisting of continental detritus; particulate organic matter; silica- and carbonate-rich, biologically produced hard materials; and void spaces filled with saline fluids of wide-ranging chemistries. Globally, there are about 3×10^8 km^3 of ocean sediment saturated with 8×10^7 km^3 of porewater that is inhabited by an estimated 3×10^{29} microbial cells.

Sediment thickness for T < 80 °C (m)



THE RESEARCH: Several global data sets (sediment thickness, bathymetry, heat flow, bottom water temperatures) were combined with modeling efforts to calculate the 3-D distribution of temperature in marine sediments. Temperature influences the thermodynamic tendency of reactions to happen, the kinetics of these reactions, the diffusion of chemical species and the physical properties (e.g., density, viscosity) of water that dictate the direction and speed of fluid flow.

TAKE-HOME: **The temperature in about 25% of global sediment is less than 20°C, conditions most preferred by cold-loving psychrophiles. However, about 75% of global sediment is less than 80°C, a temperature range suitable for extensive biological activity, including that of mesophiles and thermophiles.** Although some archaea and bacteria grow in the laboratory at temperatures higher than 100°C, even to as high as about 120°C, biotic processes in natural environments appear to be nearly inconsequential above about 80°C.

Amend and LaRowe (2016), *Microbe*, **11**, 427-432. LaRowe et al. (2017), *Geology*, **45**, 275-278.