**////Title:** **Revealing How Ocean Chemistry Controlled Earth’s Ancient Atmosphere and Microbial Evolution**

**////Standfirst:** Important clues buried within ancient rocks that were deposited on the ocean floor around one billion of years ago could help scientists understand the evolutionary history of life on Earth. Dr Romain Guilbaud and an international team of researchers from the UK and China analysed the chemical composition of these rocky sediments from the Huainan Basin in North China. Their findings demonstrate how changes in ocean chemistry occurring between one billion and 800 million years ago strongly limited the production of atmospheric oxygen, which is a necessary prerequisite for the planet to host complex life.

**////Main text:**

The evolution of complex, or multi-celled, life millions of years ago relied on the widespread oxygenation of the Earth’s atmosphere, which started around 2.5 billion years ago, at the beginning of the Proterozoic eon – a geologic time period commonly thought of as Earth’s ‘middle age’.

The global rise in atmospheric oxygen was driven by ‘phytoplankton’ – the tiny plant-like organisms in the ocean. Phytoplankton break down carbon dioxide during photosynthesis, locking the carbon into organic compounds and releasing oxygen gas into the atmosphere.

But new research from an international team of geoscientists suggests that substantial chemical changes in the oceans at the beginning of the ‘Neoproterozoic era’ – the last era of the Proterozoic eon – had dramatic impacts on the ocean’s phytoplankton. This, in turn, kept oxygen production to a minimum, hampering the shift to conditions suitable for complex organisms.

For this research, Dr Romain Guilbaud from the French National Research Centre, teamed up with geoscientists from across the world, including the University of Leeds, the University of Exeter, the Chinese Academy of Sciences, University College London, and the Nanjing Institute of Geology and Palaeontology.

The researchers made their important discovery by analysing the chemical composition of sedimentary rocks in the Huainan Basin in China. Evidence from the sediments sampled by the team, which were deposited around 1 billion years ago, suggest that phosphorous – a vital nutrient – limited the growth of phytoplankton and thus the release of oxygen into the atmosphere.

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The chemical composition of sediments on the ocean floor mainly depends on ocean conditions and how organic compounds are degraded in the sediment pile. How sediments deposited over millions of years ago can preserve this original information is another story, as many processes can destroy primary information over geologic timescales. The sedimentary rocks in the Huainan Basin, which include shales, siltstones, and mudstones, are exceptionally well-preserved and behave like a time-capsule that can help scientists understand the environmental conditions of the ancient past.

The research team collected samples of the sedimentary rocks from across the basin slopes – each of which provided a snapshot of the ocean at a particular depth within the water column. Combining a range of chemical techniques, they analysed the composition of these sediments with a particular focus on how phosphorous is distributed amongst the sediment-forming minerals and organic matter. Organic matter is an indicator of the presence and activity of living organisms: in this case, those all-important phytoplankton.

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Scientists were aware that ocean chemistry impacts global nutrient cycles, but the impact of ocean chemistry on the phosphorous cycle through geologic timescales hadn’t been investigated before Dr Guilbaud and his team carried out their research.

Their findings suggest that iron minerals are very effective at removing phosphorous from the water and locking it away, making it unavailable to living organisms. A shift in ocean chemistry during the early Neoproterozoic era, from a sulphide-rich state to an iron-rich state, therefore limited the amount of phosphorous available to the ocean’s phytoplankton. In contrast, low phosphorous levels in sediments from before the Neoproterozoic era suggest plenty of phosphorous was cycling back into the water column under the sulphide-rich ocean conditions during this period, and was therefore available for phytoplankton.

The poor phosphorous availability during the Neoproterozoic era limited phytoplankton growth and photosynthesis. Therefore, oxygen production and carbon capture were reduced, and as a result, the oxygen levels of the atmosphere were minimal. In fact, the amount of phosphorous available remained just about sufficient to prevent the oxygen levels in the atmosphere dipping below 1% of today’s level. Had atmospheric oxygen dropped below 1% of its current level, it would have tipped the planet back into a state inhospitable to complex life – like that seen during the Earth’s early development.

The emergence of complex life is believed to have occurred only once in the Earth’s history, requiring perfect alignment of the right conditions and a series of chance events. As such, reverting to an oxygen-poor atmosphere could have completely prevented the emergence of complex life.

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One question keeping scientists up at night is why complex life didn’t evolve earlier in the planet’s history. A lack of oxygen and a lack of nutrients provide two compelling reasons that may have delayed the emergence of complex life. Dr Guilbaud and the team’s study suggests that both conditions existed during the early Neoproterozoic era. The demand for oxygen exceeded supply in the deep ocean, implied by the lack of oxygen in these sedimentary records. Along with the limited amount of phosphorous available, these conditions would have made the emergence of complex life during these ancient periods exceedingly difficult, if not impossible.

It was previously believed that atmospheric oxygen levels remained relatively stable throughout the Proterozoic eon, from 2.5 billion years ago to 540 million years ago. However, the team’s findings suggest that oxygen levels in the atmosphere may have exhibited substantial variation during this time, driven by the impacts of varying nutrient availability.

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Dr Guilbaud and his collaborators have contributed substantially to our understanding of the global conditions present during the Proterozoic eon, when single-celled organisms ruled the Earth. Nutrient and oxygen levels may have undergone multiple shifts during this period, driven by and influencing the activity of the ocean’s phytoplankton. By understanding the conditions and driving forces during this period, we are one step closer to uncovering the mysteries of the evolution of complex life on Earth.

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This SciPod is a summary of the paper ‘Phosphorus-limited conditions in the early Neoproterozoic ocean maintained low levels of atmospheric oxygen’, from *Nature Geoscience.* <https://doi.org/10.1038/s41561-020-0548-7>

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