100 YEARS AGO

The inability of a large number of skilful experimental physicists to obtain any evidence whatever of the existence of the *n*-rays, and the continued publication of papers announcing new and still more remarkable properties of the rays, prompted me to pay a visit to one of the laboratories in which the apparently peculiar conditions necessary for the manifestation of this most elusive form of radiation appear to exist. I went, I must confess, in a doubting frame of mind, but with the hope that I might be convinced of the reality of the phenomena, the accounts of which have been read with so much scepticism… I am obliged to confess that I left the laboratory with a distinct feeling of depression, not only having failed to see a single experiment of a convincing nature, but with the almost certain conviction that all the changes in the luminosity or distinctness of sparks and phosphorescent screens (which furnish the only evidence of *n*-rays) are purely imaginary. It seems strange that after a year's work on the subject not a single experiment has been devised which can in any way convince a critical observer that the rays exist at all. **R. W. Wood**

From *Nature* 29 September 1904.

50 YEARS AGO

Jean Piaget's reputation as a psychologist in Great Britain is largely based upon a series of books written during 1925–32 dealing with the development of thought, language and moral judgment in the child. But, as he himself points out, this work was merely a prolegomena to his later investigations extending from 1937 to the present day… But though these researches are both theoretically and experimentally an advance upon his earlier work, they have, however, had little effect on English psychological thought… This is probably due to Piaget's introduction of a new and complex terminology, his use of symbolic logic, and the fact that his most important work remains untranslated… The most interesting conclusion which emerges from this important series of experimental researches is that mathematical concepts in their psychological development are ultimately based upon simple logical notions. Indeed, it might be said, without undue exaggeration, that Piaget's psychological studies are the genetic counterpart of Russell and Whitehead's attempt in "Principia Mathematica" to put mathematics on to a logical basis.

From *Nature* 2 October 1954.

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many ways of bringing about a low-affinity, temporary interaction with a nascent chain — many ways for a chaperone 'midwife' to hold the baby? ■

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Biogeochemistry

Early options in photosynthesis

Nicolas Beukes

Reconstruction of an ancient marine environment from 3,400-million-year-old rocks in South Africa strengthens the case for the existence of photosynthetic microbes at that time — but adds a fresh twist.

Back in 1987, publication[1] of analyses of ancient rocks in Western Australia provided some startling news — the claim, based on structures interpreted as microfossils, of the existence of life by the end of the early Archaean eon, 3,400 million years ago. Subsequent investigations[2], however, led to the suggestion that the abundant organic material found in various rocks of that age had not been generated biologically but rather by abiotic reactions in hydrothermal systems. So here were two competing views of the early Earth: one in which Earth was already inhabited by relatively complex microbes, such as cyanobacteria, that produced oxygen as a by-product of photosynthesis; and another in which the environment was dominated by hydrothermal vents and springs spewing prebiotic organic soup into an uninhabited ocean.

On page 549 of this issue, Tice and Lowe[3] add a twist to this debate with data from the 3,416-million-year-old rocks of the Buck Reef Chert in South Africa. They provide convincing evidence that the organic matter preserved in these rocks is of biological, not hydrothermal, origin. But they do not return to the view of an early Archaean Earth inhabited by oxygen-producing cyanobacteria. Rather, their picture is one in which non-oxygen-producing (anoxygenic) photosynthetic microbes existed in an ecosystem that was fundamentally different from that of today.

Like the Western Australian material that is the subject of the earlier controversy, the Buck Reef rocks are composed of chert, a sedimentary rock made almost entirely out of microcrystalline quartz. The chert contains abundant organic inclusions that have been heated to such a degree that they contain no extractable biomolecules, but which retain spectacularly preserved structures from the time of their deposition. Tice and Lowe's evidence that these carbonaceous inclusions are of biological origin comes partly from their morphology: some resemble microbial mats whereas others appear to be sand- and silt-sized grains formed by erosion of the mats.

However, the real robustness of their interpretations lies in their reconstruction of the environmental setting in which the Buck Reef Chert formed, and their ideas about how the distribution, morphology and structuring of the carbonaceous matter correlate with those settings. Tice and Lowe show that the Buck Reef Chert has three main components: a layer that was deposited in evaporative ponds behind an old shoreline; a carbon-rich, black-and-white-banded chert unit, deposited in a shallow nearshore environment that was occasionally stirred by storms and large waves; and a banded, iron-rich chert that formed offshore, below the base of storm waves at depths of more than 200 m.

From this reconstruction of sedimentary environments, the authors conclude that the mat-like organic laminations in black chert apparently had ecological control over their distribution. The laminations are only present in banded chert, deposited in a shallow marine environment, within the depth to which light could penetrate the water column (the euphotic zone). The distribution of these distinctive organic morphologies is best explained by their being of biological origin.

This result takes our understanding of early Archaean biota beyond the hydrothermal debate, and greatly improves the case for the existence of photosynthetic organisms in the early Archaean. Previous arguments for that rested primarily on interpretations of the morphologies of microfossils[1], and structures presumed to have been formed by cyanobacteria (stromatolites), and on the carbon isotopic composition of early organic

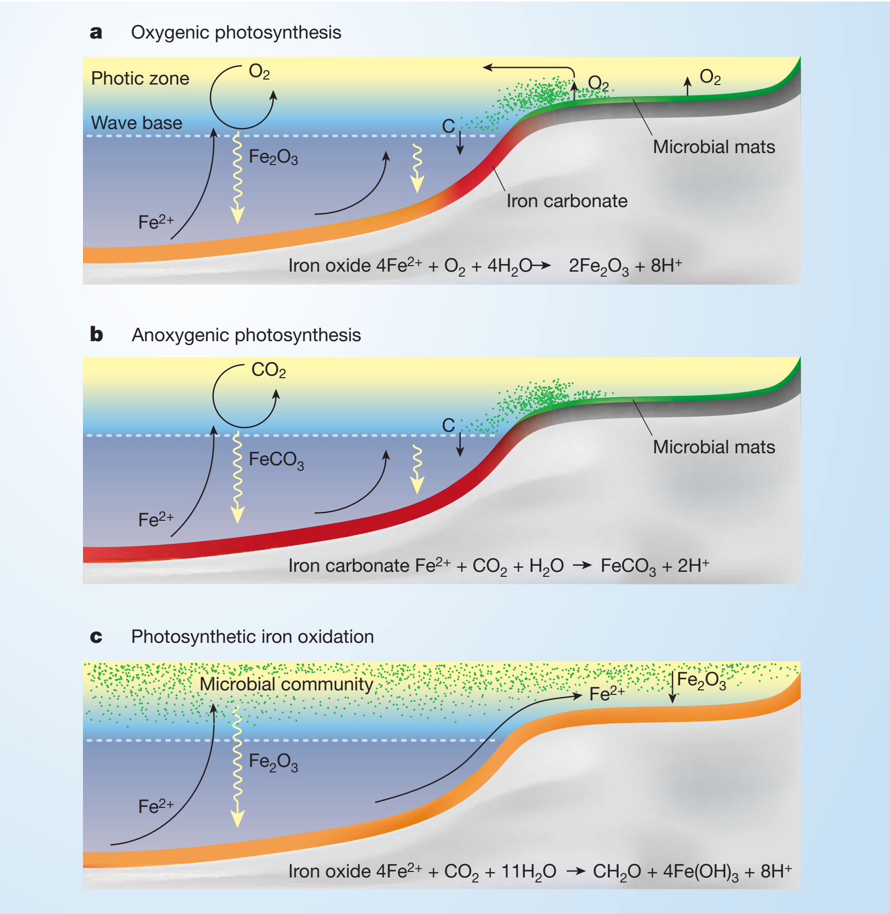

Figure 1 **Contrasting models of iron-mineral deposition in the Archaean ocean.** a, **The classical model[5], in which free oxygen, ultimately derived from oxygenic microbial photosynthesis, precipitates iron oxides from a stratified ocean. Iron carbonate ($FeCO_3$) can form in intermediate environments between the deep- and shallow-water settings.** b, **A model, based on Tice and Lowe's data[3] from the Buck Reef Chert, of iron-carbonate formation under anaerobic conditions from a stratified ocean with a CO_2-rich upper layer. Here, photosynthesis is anoxygenic and no iron oxides are precipitated.** c, **A recent model that requires dissolved ferrous iron to be present in the euphotic zone for oxidation by anaerobic photosynthetic bacteria[6] in the open ocean. In** a **and** b, **deposition of the iron minerals is decoupled from primary biological productivity; in** c **it is directly coupled.**

matter[4]. Both types of evidence were ambiguous for deposits of that age. Tice and Lowe's combination of data — carbon isotopic evidence and the apparent restriction of microbial mats to the euphotic zone — makes a much stronger case for photosynthesis as the primary mode of carbon fixation by microbial communities during deposition of the Buck Reef Chert.

But what kind of photosynthetic microbes were present? Here the iron-rich chert, representing the deep-water deposits of the Buck Reef Chert, is the key to Tice and Lowe's interpretation. It is composed of alternating bands of relatively pure white chert and chert containing fine laminations of iron carbonate ($FeCO_3$, also known as siderite). It is analogous to the iron-carbonate formations commonly seen in the transition from black carbonaceous chert to iron-oxide (Fe_2O and Fe_3O_4) deposits in many iron formations[5]. Models of iron deposition suggest that iron minerals periodically precipitated at the mixing interface of a deep, iron-rich layer and a shallow, iron-depleted layer in a stratified Archaean ocean[5]. As Tice and Lowe point out, the abundance of iron carbonate in the deep-water deposits of the Buck Reef Chert, and its scarcity or absence in the shallow-water deposits, support this general concept of a stratified ocean.

Classic models of the deposition of iron minerals invoke the presence of free oxygen in shallow water to account for precipitation of iron oxide (Fig. 1a). In these models, iron carbonate is derived from reduction of iron oxide by organic matter washed in from shallow, nearshore environments. However, based on the observations that primary sedimentary iron oxides are absent from deep-water iron-rich chert, and that iron carbonate is found both in isolation and associated with carbonaceous matter in the Buck Reef Chert, Tice and Lowe[3] propose that iron carbonate was directly precipitated from sea water. They thus favour the existence of an anaerobic environment in which anoxygenic photosynthetic microbes inhabited the euphotic zone on a shallow platform (Fig. 1b). Iron carbonate precipitated deeper down, at the interface between a deep iron-rich layer and a shallow CO_2-dominated layer in the Archaean ocean.

In recent years, a popular model for iron deposition during the Archaean has been one in which anaerobic photosynthetic bacteria oxidize ferrous iron in the euphotic zone, resulting in the precipitation of ferric iron oxides (Fig. 1c)[6]. Another possibility is that photochemical oxidation of ferrous iron under anaerobic conditions produced the same result[7]. But Tice and Lowe's reconstruction of the Buck Reef Chert shows that the entire euphotic zone of the stratified water column was depleted in iron. So it is unlikely that either of these two light-dependent mechanisms could have been in operation. Because they are the only known mechanisms that can oxidize ferrous to ferric iron under anaerobic conditions, it follows that free oxygen must have been available to produce the iron-oxide formations laid down during the Archaean. Many such formations are known in middle to early Archaean deposits, including that at Isua, Greenland[8], which is about 3,800 million years old.

There are two known processes that could have produced free oxygen in Archaean times: light-mediated dissociation of water vapour in the upper atmosphere, and bacterial photosynthesis. Most models predict that oxygen production from water vapour would have been insignificant; it is also hard to imagine how that oxygen could have been transported through an otherwise reducing atmosphere and come into contact with the reduced iron dissolved in ocean water. Despite Tice and Lowe's conclusion that anoxygenic photosynthetic microbes were present during deposition of the Buck Reef Chert, does this mean that oxygenic photosynthesis developed very early on in Earth's history — perhaps even before deposition of the 3,800-year-old Isua formation?

This is a hypothesis that has been around for some time[9], and Tice and Lowe provide a guide as to how to test it more rigorously in future. Before drawing conclusions about the global nature of environments or ecosystems early in the world's history, we need detailed field studies on iron formations and associated rocks in as many Archaean settings as possible to evaluate the geochemical and biological legacy left by local conditions. ■

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