PERSPECTIVE

“Algae and Oxygen, Humans and Carbon: A Precambrian Analogue for the Anthropocene”

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Abstract: In 2003 Paul Crutzen and Will Steffan asserted that across Earth’s 4.5 billion year history no analogue could be found for the Anthropocene. An analogue, however, can be located in the dim Precambrian past when, through oxygenic photosynthesis, cyanobacteria produced enough oxygen to alter the composition and character of the Earth-system. The “Great Oxygenation Event” that followed wiped out much of Earth’s anaerobic life while giving rise to all subsequent aerobic life. It also offers a clear comparison to the Anthropocene that implicates how we think about our current predicament.

Key Words: Anthropocene; Great Oxygenation Event; cyanobacteria;

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It is not hard to conclude that Earth, or at least the ecological niches that humans inhabit, is poised on a rather fine point. While our species lays claim to about one-third of the Earth's productive capacity, just 20% of the human population accounts for 80% of the total anthropogenic greenhouse gas emissions (Lewis and Maslin, 2015; Mikhail, 2016). Such imbalanced output has had an outsized impact on everything from an atmosphere the carbon content of which is predicted to double over the course of the current century to a rise in the global mean temperature of between 2.0 and 4.5 degrees centigrade (Lo et al, 2017). Tens of thousands of species are now reckoned to vanish annually while the Earth's vertebrate population alone has declined by 28% since 1970. A similarly dismal story could be told for our invertebrate cousins as well (Dirzo, 2014). Climate change and species extinction, however, have also been regular features of the Earth's history since life first appeared. What sets the current crisis apart from previous eras and eons of climate change and biological interruption is the fact that the variables that have driven recent changes relate overwhelmingly to our species' actions and activities. The salience of such productive and consumptive activity and its potentially catastrophic consequences has led the creators of the idea of the Anthropocene to conclude that we live in a "no-analogue" state against which no past era in Earth's 4.5 billion year history can compare (Crutzen and Steffen, 2003, 253).

But there is an analogue--the Great Oxygenation Event.

Earth's first lifeforms, anaerobic microbial cells, emerged into a world that lacked oxygen to respire and ozone to shield the surface from the sun's deadly rays (Fischer et al, 2016; Rozhnov, 2013). Such life had to live beyond the sun's reach

buried in the soil; suspended in rivers, lakes, ponds and the sea; or gathered in the ocean's depths around geothermal vents where it reduced hydrogen, sulphur, methane, or iron into the energy it needed to survive. What little atmospheric oxygen there was had appeared only slowly after millions of years of the climatic weathering of minerals until the rise of the first aerobic photosynthetic organisms triggered the Great Oxygenation Event. Cyanobacteria, also known as blue-green algae and often the cause of the present-day algae blooms that poison our rivers and lakes, had evolved from an evolutionary fusion of two antecedent forms of anoxygenic photosynthesis that enabled them to use the limitless energy of the sun rather than the finite power of hydrogen, sulphur, methane or iron to split water into hydrogen--from which they derived energy--and oxygen--which they released as a by-product of their life processes (Lyons et al, 2014; Canfield, 2014). Because oxygenic photosynthesis yields far more energy than anoxygenic photosynthesis, the resulting explosion of the cyanobacteria population began to augment Earth's small geochemical supply of oxygen through their ongoing exhalations (Anbar, 2007; Canfield, 2014; Canfield, 2005; Lyons et al, 2014; Sciuto and Moro, 2015).

Cyanobacteria colonies floated like vast mats in the upper reaches of Earth's oceans and may have also colonized the primordial seas' shallow shores (Rozhnov, 2013). Over millions of years the oxygen they produced pooled in scattered sinks which then oxygenated the atmosphere in fits and starts in rough conjunction with ongoing and fluctuating tectonic and volcanic processes (Canfield, 2014). A steep decline in atmospheric oxygen around 2 billion years ago then rebounded and resulted in a huge jump from 0.0002% to 0.2% of the atmosphere (Rozhnov, 2013; Fischer et al, 2016). Then, as volcanic activity ebbed and the Earth cooled oxygen

levels stabilized at 0.2-0.3% before steadily accumulating over the eons to present-day levels (Canfield, 2014; Rozhnov, 2013; Sciuto and Moro, 2015).

No matter the remoteness, the complexity, and the still unanswered questions that surround the rise of the cyanobacteria and their relationship to the Great Oxygenation Event, their relevance to the Anthropocene is clear. A lifeform evolved over time and innovated a new way to sustain itself that altered the Earth-system in planet-changing ways. The cumulative effect of their photosynthetic respiration thus initiated the oxygenic atmosphere that made possible all subsequent aerobic life on Earth (Anbar, 2007, Canfield, 2005; Frank et al, 2017) which, at the same time, proved lethal to most anaerobic life and triggered one of the largest mass extinctions in Earth's history (Sciuto and Moro, 2015; Fischer et al, 2016).

Taking such a broad look at such a vast past has a way of stripping things to the basics and sets the cyanobacteria and humans as peers of a kind; two distinct forms of life that acquired the capacity to change the Earth-system because of how the by-products of their life processes interacted within the system that had made them possible in the first place. Most scholars of the Anthropocene, however, do not recognise such commensurability and posit instead a fundamental difference between “natural” processes like photosynthesis and “unnatural” processes such as anything done by humans (Hamilton, 2015; Maslin and Lewis, 2015). Indeed, the categories “natural” and “unnatural” are ubiquitous throughout the anthropocenic literature, notwithstanding scholarly critiques that have exploded the false dichotomy so often drawn between humans and nature (Latour, 1993; Bonneuil and Fressoz, 2017). The literature, for example, regularly juxtaposes environmental effects caused by “natural variability” or “natural behaviour (Crutzen and Stoerman, 2000, 17)” against “human induced processes (Dotterweich, 2014, 22).” The separation of the

human from the natural reaches back through the Enlightenment all the way to the monotheistic foundations of the Abrahamic faiths that posited God's alienation of humankind from the rest of His Creation (White, 1967; Akenson, 1998; Smythe, 2014; Mikhail, 2016). Its unreflexive perpetuation within anthropocenic thought thus expresses a religiously- and historically-specific understanding of the world and our place within it (Cronon, 1996) which then sustains the broad conclusion that the Anthropocene is unnatural and, consequently, without analogue in Earth's history.

When the book Gaia appeared in 1979 its author, JE Lovelock, likened the Great Oxygenation Event, in full and clear irony, to the "greatest pollution disaster to ever affect our planet (1979, 109)." Recognizing the fallacy and folly of indicting the cyanobacteria as first-class industrial polluters, however, he instead focused on the paradox of life and how the character of life shapes the composition of the Earth-system so that when life changes the Earth-system also changes in cyclical rhythms that have operated on Earth for the past 3 billion years. The most significant driver of such change, he concluded, was nothing more than life itself (Lovelock, 1979).

What the Anthropocene's analogue, the Great Oxygenation Event, exposes is the fact that neither industrial technology, rampant consumerism, nor moral failure are necessary ingredients for climatic and biological change or catastrophe. The processes of life, the passage of time, and the dynamism of the Earth, by contrast, are. To be sure, differences between the two analogues abound. Whereas the first played out over millions of years, the second has, depending on to which school of Anthropocenic thought one defers, lasted at least fifty years (Crutzen and Steffen, 2003; Waters et al, 2016a; Waters et al, 2016b), probably two-plus centuries (Crutzen and Steffen, 2003), possibly half of a millennium (Koch et al, 2019), or perhaps even thousands if not tens of thousands of years (Ruddiman, 2013; Lewis

and Maslin, 2015). Whereas the cyanobacteria engaged universally, as far as can be told, in climate-changing behaviour, it is also reasonable to draw the circle of culpability for the Anthropocene around a fairly small though disproportionately powerful subset of the human species (Hamilton, 2016; Mikhail, 2016; Bashford, 2013; Delanty and Mota, 2017). And if the Great Oxygenation Event can be interpreted in a remote and relatively dispassionate way, the Anthropocene strikes at our deepest senses of morality and mortality perhaps because of the most important existential difference between the two events—we understand our role in altering the Earth-system while the cyanobacteria probably did not. But if one lifeform's pointed awareness of its impact on the Earth-system differs from the other, their causal roles, irrespective of consciousness, remain the same.

What of the similarities? Despite their differences in scale, scientists have fixed both within the same geological reckoning of linear time. Both events derived from essential, inherent, and specific life processes. Both involved a lifeform finding a way to utilise energy in ever more efficient and potentially lethal ways. And the first culminated--while the second shows every sign of repeating the same pattern--in events that altered the course of life on Earth involving equal helpings of vast destruction and profound creation. If the analogue to the supposedly “no-analogue” state has anything to tell, then, it is that a monotheistically-derived scientific sense of anthropocentric and anthropocenic exceptionalism, more so than the chemical by-products of our consumption, perhaps puts us most in peril because it leads us to deny the implacable fact that both the Anthropocene and its analogue were and are wholly consistent with the destructive and creative processes of life and perhaps even normal and unremarkable when set against the broad sweep of Earth's billions of years.

References

- Akenson DH (1998) *Surpassing Wonder: The Invention of the Bible and the Talmuds*. Kingston: McGill-Queen's University Press.
- Anbar, AD, Romaniello SJ, Allenby BR, Broecker WS (2016) "Addressing the Anthropocene." *Environmental Chemistry* 13: 777-783.
- Bashford A (2013) "The Anthropocene in Modern History: Reflections on Climate and Australian Deep Time." *Australian Historical Studies* 44: 341-349.
- Bonneuil C, Fressoz J-B (2017) *The Shock of the Anthropocene: The Earth, History and Us*. Fernbach D (trans.). London: Verso.
- Canfield DE (2005) "The Early History of Oxygen: Homage to Robert M. Garrels." *Annual Review of Earth and Planetary Science* 33: 1-36.
- Canfield DE (2014) *Oxygen: A Four Billion Year History*. Princeton, NJ: Princeton University Press.
- Canfield DE, Glazer, AN, Falkowski PG (2010) "The Evolution and Future of Earth's Nitrogen Cycle." *Science* 330: 192-196.
- Cronon W (1996) "The Trouble with Wilderness: Or, Getting Back to the Wrong Nature." *Environmental History* 1: 7-28.
- Crutzen PJ, Steffen W (2003) "How Long Have We Been in an Anthropocene Era? An Editorial Comment." *Climatic Change* 61: 251-257.
- Crutzen PJ, Stoerman E (2000) "The 'Anthropocene.'" *International Geosphere-Biosphere Newsletter* 41: 17-18.
- Delanty G, Mota A. (2017) "Governing the Anthropocene: Agency, Governance, Knowledge." *European Journal of Social Theory* 20: 9-38.
- Dirzo R, Young HS, Galetti M; Ceballos G, Nick IBJ, Collen B (2014) "Defaunation in the Anthropocene." *Science* 345: 401-406.

- Dotterweich M, Ivester AH, Hanson PR, Larsen D, Dye DH (2014) "Natural and Human-induced Prehistoric and Historical Soil Erosion and Landscape Development in Southwestern Tennessee, USA." *Anthropocene* 8: 6-24.
- Fischer WW, Hemp J, Valentine JS (2016) "How Did Life Survive Earth's Great Oxygenation?" *Current Opinion in Chemical Biology* 31: 166-178.
- Frank A, Kleidon A, Alberti M (2017) "Earth as a Hybrid Planet: The Anthropocene in an Evolutionary Astrobiological Context." *Anthropocene* 18: 13-21.
- Hamilton C (2015) "Getting the Anthropocene so Wrong." *Anthropocene Review* 2: 102-107.
- Hamilton C (2016) "The Anthropocene as Rupture." *Anthropocene Review* 3: 93-106.
- Koch A, Brierley C, Maslin MA, Lewis, SL (2019) "Earth System Impacts of the European Arrival and Great Dying in the Americas after 1492." *Quaternary Science Reviews* 207: 13-36.
- Latour B (1993) *We Were Never Modern*. Trans. Catherine Porter. Cambridge: Harvard University Press.
- Lewis SL, Maslin MA (2015) "Defining the Anthropocene." *Nature* 519: 171-180.
- Lo L, Chang S-P, Wei K-Y et al (2017) "Nonlinear Climatic Sensitivity to Greenhouse Gases over Past 4 Glacial/Interglacial Cycles." *Scientific Reports* 7: 1-7.
- Lovelock JE (1979) *Gaia: A New Look at Life on Earth*. Melbourne: Oxford University Press.
- Lyons TW, Reinhard CT, Planavsky NJ (2014) "The Rise of Oxygen in Earth's Early Ocean and Atmosphere." *Nature* 506: 307.
- Maslin MA, Lewis SL (2015) "Anthropocene: Earth System, Geological, Philosophical and Political Paradigm Shifts." *Anthropocene Review* 2: 108-116.

Mikhail A “Enlightenment Anthropocene.” (2016) *Eighteenth-Century Studies* 49: 211-231.

Rozhnov SV (2013) “At the Dawn of the Aerobic Biosphere: The Effect of Oxygen on the Development of Biota in the Proterozoic and Early Palaeozoic.” *Paleontological Journal* 47: 961-972.

Ruddiman WF (2013) “The Anthropocene.” *Annual Review of Earth and Planetary Sciences* 41: 45-68.

Sciuto K, Moro I (2015), “Cyanobacteria: The Bright and Dark Sides of a Charming Group.” *Biodiversity Conservation* 24: 711-738.

Smythe KR (2014) “Rethinking Humanity in the Anthropocene: The Long View of Humans and Nature.” *Sustainability* 7: 146-153.

Waters CN, Zelasciewicz J, Summerhayes C et al (2016a) “The Anthropocene is Functionally and Stratigraphically Distinct from the Holocene.” *Science* 351: 2622-1 to 2622-10.

Waters CN et al (2016b) “Review Summary.” *Science* 351: 137.

White, Jr L (1967) “The Historical Roots of Our Ecologic Crisis.” *Science* 155: 1203-1207.